CITY OF FOSTER CITY, CALIFORNIA

SEISMIC SAFETY ELEMENT OF THE GENERAL PLAN

Prepared by: Foster City Planning Department

July, 1979

RESOLUTION NO. 79-98

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF FOSTER CITY ADOPTING THE SEISMIC SAFETY AND (PUBLIC) SAFETY ELEMENTS OF THE CITY OF FOSTER CITY GENERAL PLAN

CITY OF FOSTER CITY

BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF FOSTER CITY, as follows:

WHEREAS, on August 2, 1979 the Planning Commission did by Resolution No. P-66-79 approve the Seismic Safety and (Public) Safety Elements as presented by the Planning Department Staff, finding said Elements to conform to the requirements of Article 5, Chapter 3 of Title VII, California Government Code, and the State Resources Agency Environmental Quality Act Guidelines Section 15148; and

WHEREAS, the Planning Commission did recommend that the City Council adopt said Elements, after consideration of the findings, policies and recommendations therein, as parts of the Foster City General Plan; and

WHEREAS, after due notice, the City Council did on September 4, 1979 open, hold and close a Public Hearing on these matters; and

WHEREAS, the City Council finds the content of the studies and the actions of the Planning Commission to be complete, correct and in satisfaction of applicable law.

NOW, THEREFORE, BE IT RESOLVED that the City Council of the City of Foster City hereby approves and adopts said Seismic Safety and (Public) Safety Elements as parts of the Foster City General Plan.

PASSED AND ADOPTED as a Resolution of the City Council of the City of Foster City at the Regular Meeting held on the 4th day of September, 1979, by the following vote:

AYES: Councilmen Chavez, Gilbert, Kruss, Matsuo, and Mayor Zimmerman

NOES: None

ABSENT: None

ABSTAIN: None

Gilbert S. Zimmerman

GILBERT S. ZIMMERMAN, MAYOR

ATTEST:

Andrea M. Pavone

ANDREA M. PAVONE, CITY CLERK

RESOLUTION NO. P-66-79

A RESOLUTION OF THE PLANNING COMMISSION OF THE CITY OF FOSTER CITY -- TO AMEND THE FOSTER CITY GENERAL PLAN BY ADOPTION OF A SEISMIC SAFETY ELEMENT AND A (PUBLIC) SAFETY ELEMENT AS PARTS OF SAID GENERAL PLAN (GP-3-79)

CITY OF FOSTER CITY PLANNING COMMISSION

BE IT RESOLVED BY THE FOSTER CITY PLANNING COMMISSION, as follows:

WHEREAS, Article 5, Chapter 3 of Title VII, California Government Code, requires Cities and Counties to include Seismic Safety and (Public) Safety Elements as parts of their General Plans; and

WHEREAS, the City of Foster City has conducted such studies and, after due notice, the Planning Commission did on August 2, 1979 open, hold and close a Public Hearing on these matters; and

WHEREAS, the Planning Commission finds the studies as presented by Staff to be complete and correct and in satisfaction of the requirements of State law, as to the Government Code and the State Resources Agency Environmental Quality Act Guidelines Section 15148.

NOW, THEREFORE, BE IT RESOLVED that the Planning Commission hereby approves the Seismic Safety and (Public) Safety Elements and recommends that the City Council adopt said Elements, after consideration of the findings, policies and recommendations therein, as parts of the Foster City General Plan.

Passed and adopted by the Planning Commission of the City of Foster City at a regular meeting thereof held on August 2, 1979 by the following vote:

AYES, COMMISSIONERS:	Broomhead, Chinn, Kundupoglu, Oliver, and Chairman Fitzgerald.
NOES, COMMISSIONERS:	None.
ABSENT, COMMISSIONERS:	None.
ABSTAIN, COMMISSIONERS:	None.

Robert J. Fitzgerald

ROBERT J. FITZGERALD
Chairman of Foster City Planning Commission

ATTEST:

Robert M Stewart

ROBERT M. STEWART
Secretary to Planning Commission

COMPLIANCE WITH CALIFORNIA ENVIRONMENTAL QUALITY ACT GUIDELINES - SECTION 15148

This document meets the requirements of the California Environmental Quality Act which allows for the waiver of a separate Environmental Impact Report if the following points have been addressed:

1. Description of the project, to be found in Sections 1100 through 1324, inclusive.

2. Description of environmental setting -- Section 2115, Sections 3000 through 3319; 3324 through 3355; 3367 through 4341.

3. Environmental impact -- Sections 1420 through 1424, inclusive; Sections 3300 through 3348, inclusive.

4. Mitigation measures -- Section 3349, et seq.

ALTERNATIVES

The City of Foster City considered two alternatives to adoption of the Seismic Safety Element:

1. Adoption of the San Mateo County Seismic Safety Element -- for reasons explained in the mitigation section of this element, the County of San Mateo element was found to be too general in its discussions of the conditions peculiar to Foster City.

2. Provision of no element at all would be clearly in violation of the Government Code, Section 65302.2.

A list of the persons contacted, including the bibliography reference, appears in the back of this document.

The adopted General Plan Element will be sent to the County of San Mateo and the following Cities:

1. San Mateo

2. Belmont

3. Redwood City

A Notice of Determination will be issued on the adoption of this General Plan Element.

TABLE OF CONTENTS

FOSTER CITY SEISMIC SAFETY ELEMENT

SUMMARY OF THE SEISMIC SAFETY ELEMENT OF THE GENERAL PLAN FOR THE CITY OF FOSTER CITY

The Foster City Seismic Safety Element is a mandated document under Sections 65302 and 65302.1 of the California State Code. The Seismic Safety Element consists of an identification and appraisal of local seismic hazards such as susceptibility to surface rupture from faulting, susceptibility to seismically-induced waves, including tsunamis and seiches. If follows, therefore, that under the State Guidelines, the Seismic Safety Element is a public policy for relating the City's programs for land use planning, the provision of public improvements, and the development (or redevelopment) of land to Foster City's seismic characteristics.

The first portion of the document deals with a general overview of the mechanism of earthquakes. This initial section includes a general description of the earth's geology, crustal plates and their function, fault lines, earthquakes and how they are measured, ground shaking, surface rupture, ground failure, tsunamis and seiches, and seismic predictions.

The second portion of the document discusses specific geotechnical hazards as they pertain to the Foster City situation. Initially, the geology of Foster City is delineated, specifically the seismic characteristics of the so-called Bay Muds. Following this, the pre-existing conditions of the Foster City area are presented, including the pre-existing conditions of the crusted areas, the salt pond areas and the marsh areas. Emphasis is also placed on the existing geologic conditions (prior to 1960) that might negate the development of Brewer Island as a planned community.

The Foster City Seismic Safety Element addresses the major seismic issues of liquefaction, tsunamis and seiches, inundation by failure of San Andreas and Crystal Springs Dams, plus consideration of seismic risk to the levee system. The maintenance program implemented to provide for the continued integrity of the levee system is also examined. In the remainder of the document, all issues listed under Section 65302 of the California State Code are presented.

The report accentuates the impact of potential and active faults in the San Francisco Bay Area on San Mateo County, and more specifically, on Foster City. The San Andreas and Hayward faults are thoroughly discussed, together with the faults found within San Mateo County.

The Foster City Seismic Safety Element renders an analysis of the San Francisco Regional Preparedness Plan. Mention is also made of the Foster City Earthquake Emergency Plan.

Finally, a series of findings and conclusions are presented, together with specific recommendations for implementation of these findings and conclusions.

1000. *INTRODUCTION TO THE SEISMIC SAFETY ELEMENT*

1100. INTRODUCTION

1110. General Description of Seismic Safety Element

1111. The land use planning process in Foster City is an on-going exercise reflecting the coordination of environmental, social, and economic concerns of this City. The desire of the Planning Department is to develop policies that will attain the needs and desires of the residents of the City. In an age of environmental concerns, seismic safety and safety planning is of paramount concern to the attainment of land use goals within the political boundaries of the City.

1112. Safety planning relates primarily to the avoidance or reduction in loss of life, injury, and property damage resulting from natural hazards. Since hazards are measured in terms of potential losses, based upon human activity, the degree of hazards can be evaluated and partially controlled by the extent and intensity of human activity in the hazard-prone area.

1113. The Seismic Safety Element will attempt to define the natural hazards in Foster City, evaluate their potential for loss and destruction, and present policies and programs for reducing the risk the hazards represent.

1120. County Element and Problems

1121. Joint Venture:

1122. Since seismic and other public hazards do not by nature respect legal boundaries, a joint project to examine the Seismic Safety and Safety Element was undertaken in 1975-76 as a cooperative effort between the County of San Mateo, the Towns of Hillsborough, Portola Valley, and Woodside and the Cities of Belmont, Brisbane, Burlingame, Daly City, Foster City, Half Moon Bay, Menlo Park, Redwood City, San Bruno, San Carlos, and South San Francisco.

1123. Coordinated input was received from the Joint Cities/County Planning Task Force, an advisory subcommittee of the County Regional Planning Committee. The Task Force was composed of the managers, engineers, and planners of each Town and City in the County, and their counterparts from the County staff.

1124. In addition to the above, the County also employed the services of Engineering Decision Analysis Company (EDAC) as risk analysis consultants and Leighton and Associates as geotechnical consultants.

1125. Qualification of Data and Conflict Between Experts Regarding Seismic Hazards in Foster City:

1126. The final document consisted of Volume One: Goals, Policies, and Programs, and Volume Two: Technical Supplement. This document is intended to serve three purposes, in addition to fulfilling the legal mandate of the State Code. These purposes are:
1) to identify, delineate, and evaluate potential natural hazards, including geotechnical and fire hazards;
2) to integrate data on geotechnical and other natural hazards into the decision-making process at the local level; and
3) to provide policy guidance to the decision-makers of the participating jurisdictions.

1127. The County Element investigates and thoroughly describes the various geotechnical hazards that exist throughout the County and demarks their locations on the San Mateo County Hazards Map. It should be understood that the County Element has been developed from data compiled and prepared by other agencies. The Element does not introduce new geotechnical data, but only consolidates such information into the document. For example, dam inundation caused by the failure of Crystal Springs and San Andreas Dams was based upon maps developed by the City of San Francisco Water Department as part of the State of California's Office of Emergency Preparedness requirements. These maps were prepared in order to describe maximum limits of damage and estimate the cost of disaster funding. In other words, the data was intended for one purpose and is being used to describe another. It is important, therefore, to understand that the County makes no claims to the validity of the data since that data has been developed by other sources.

1200. AUTHORITY

1210. According to State law, the Seismic Safety Element must consist of an identification and appraisal of seismic hazards such as susceptibility to surface rupture from faulting, to ground shaking, to ground failures, or to the effects of seismically-induced waves, tsunamis, or seiches. State law requires that the Seismic Safety Element shall also include an appraisal of mudslides, landslides, and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards. The Seismic Safety Element is pursuant to Sections 65302 and 65302.1 of the State Code.

1300. PURPOSE

1310. Intent:

1311. The objective of the Seismic Safety Element is the identification of areas of possible seismic hazards within Foster City and the effect seismic-caused events in other areas of California will have

in Foster City. Moreover, it is the intention of this report to meet the regulations set forth in the California Government Code Sections 65302 (F) and 65302.1. Also, like any other General Plan Element, the Seismic Safety Element will include a program for the implementation of policies and recommendations pursuant to Sections 65302 (F) and 65302.1.

1312. It follows, therefore, that the Seismic Safety Element is a public policy for relating the City's programs for land use planning, the provision of public improvements, and the development (or redevelopment) of land to Foster City's seismic characteristics. Although attention has been given historically to the performances of buildings and structures during earthquakes, comparatively little attention has been directed to the subject of how land uses should be distributed or building development laid out on a seismically active landscape.

1320. Impact of Seismic Hazards on the Planning Process

1321. In general, all faults should be given consideration in the planning process. Structures intended for human occupancy must not be erected over an "active" fault trace and to the extent practicable, structures intended for human occupancy should not be erected over the trace of an "inactive" fault. Setbacks should take into account the varying degree of seismic risk and consequences of failure.

1322. To the extent practicable, structures which affect the provision of needed services (e.g., highway interchanges, utilities) should not be erected over the trace of an active or potentially active fault. Where it is deemed essential to do so for the public welfare, these structures should be designed to accommodate or minimize the effects of fault displacement and seismically-triggered ground failure.

1323. Land in the setback areas along active and potentially active fault traces should be utilized for open forms of land use that could experience displacement without endangering large numbers of people or creating secondary hazards. Examples are yards, greenbelts, parking lots, and non-critical storage areas. Roads, particulary those which carry large volumes of traffic, should be sited over active faults only where other alternatives are impractical.

1324. A geologic investigation and report should be required for all subdivisions and planned unit developments which are crossed by mapped faults. Because of the relatively greater significance of the major fault systems, subdivisions and planned unit developments within approximately 1/8 miles of such a fault should have geologic reports.

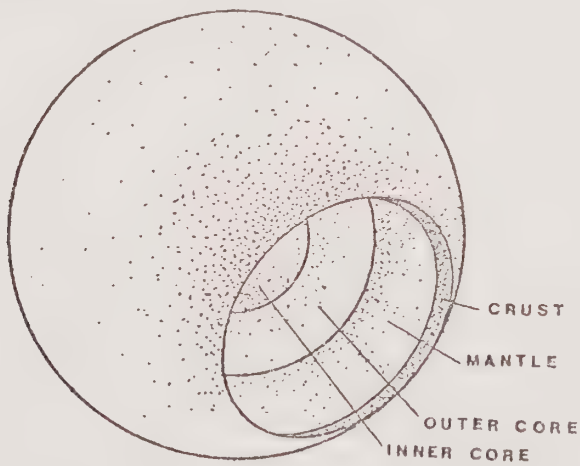
2000. *BACKGROUND*

2100. OVERVIEW

2110. To better understand the problems and concerns of seismic hazards pertaining to Foster City, a general discussion of seismic geology will be presented.

2111. <u>Description of Earth's Basic Geology</u>

2112. As an almost spherical body, the earth has an equatorial radius of approximately 3,960 miles. A solid inner core of about 800 miles (See Figure 1) radius is surrounded by what is believed to be mostly a liquid zone having a distance of about 1,400 miles. Outside this liquid zone is the mantle composed of mineral matter in a solid state. This mantle zone is about 1,800 miles thick. The outermost and thinnest of the earth's zones is the crust with a thickness of about 40 miles. The continents, oceans, and ocean basins compose the major portion of the earth's crust. The crust, however, is not neolithic, or one piece, but consists of several plates which rest on the mantle.

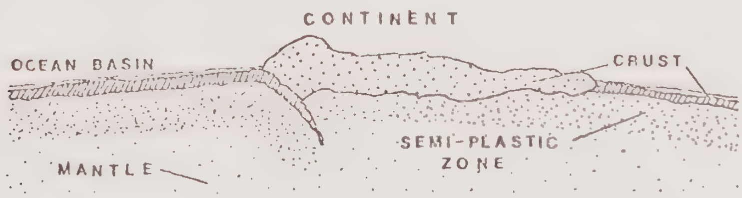


EARTH'S INTERIOR

Figure 1

2113. Crustal Plates and How They Function

2114. Sliding over a hot, semiplastic layer existing between the crust and the mantle, the rigid plates grind and crush together, causing earthquakes and volcanic eruptions (See Figure 2). The plates crack, usually in the ocean basins where they are the thinnest and the pieces move apart. In the cracks molten rock wells up and solidifies, along other edges the plates are just as steadily destroyed. They bend downward, forming the deep oceanic trenches, and slide beneath an opposing plate or edge of a continent to be consumed within the earth's interior. The boundary lines between the crustal plates are not always readily distinguishable on the earth's surface.



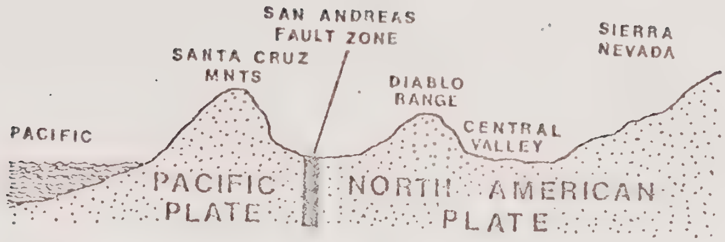
INTERFACING BETWEEN CRUST AND MANTLE

Figure 2

2115. Fault Lines

2116. The San Andreas fault system which generally passes through the California coastal region and more specifically through San Mateo County represents the boundary line between the Pacific Plate, consisting of the coastal mountain range, and the American Plate, consisting of the North American continent east of the fault line (See Figure 3). This fault line is not always identifiable on the earth's surface. There are, however, land forms and geologic criteria and instrumentation which can be used to map its location.

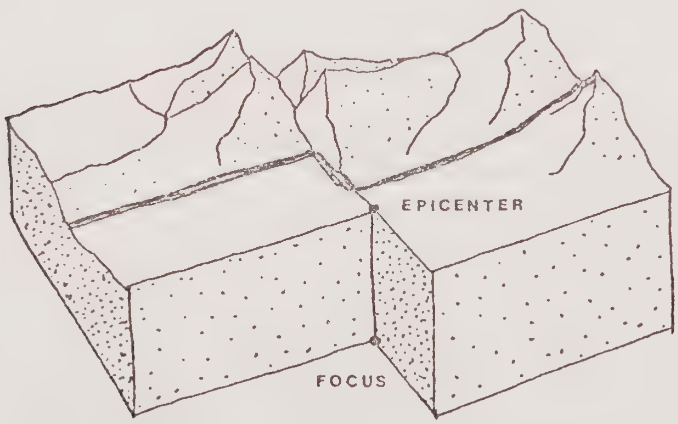
2117. A fault is not one solid continuous line, but consists of a system of fault traces which appear on the earth's surface. A fault trace is a term which describes a line on the surface formed where the fault intercepts the surface. Where the edge between plates lock but the plates continue to move, the boundary rock bends or strains, until it finally snaps along the fault and shifts violently back toward equilibrium like a bent stick breaking. This shifting reaction creates the devastating shock waves known as earthquakes. It is this shaking, not the actual surface rupture of the fault, that causes most of an earthquake's damage. A major earthquake may destroy buildings 10 miles or more away as easily as those 100 feet away from the fault.



SAN ANDREAS FAULT ZONE
BOUNDARY BETWEEN CRUSTAL PLATES

Figure 3

2118. Earthquakes can occur at various depths within the fault area. The point below the surface where the actual rupture occurs is called the focus and its location can be determined by seismic instruments (See Figure 4). The epicenter is measured in two ways. The instrumental epicenter is a point on the earth's surface directly above the focus, however, this point may not be the area of maximum ground shaking or damage. The epicenter is defined as the point of strongest ground shaking. The field epicenter may not coincide with the instrumental epicenter.



EARTHQUAKE - FOCUS & EPICENTER

Figure 4

2119. Earthquakes and How They Are Measured

2120. Earthquakes vary in their effects. They can range from a minor disturbance to a major catastrophe. There are two systems which have been developed to measure earthquakes and compare them with each other: the Richter Scale and the Modified Mercalli Scale. The Richter Scale basically measures the magnitude of the earthquake. In other words, it measures the energy released by the earthquake and assigns a number to such magnitude (See Figure 5).

THE RICHTER SCALE

EARTHQUAKE MAGNITUDE	APPROXIMATE EARTHQUAKE ENERGY
1.0	6 ounces TNT
1.5	2 pounds TNT
2.0	13 pounds TNT
2.5	63 pounds TNT
3.0	400 pounds TNT
3.5	1 ton TNT
4.0	6 tons TNT
4.5	32 tons TNT
5.0	200 tons TNT
5.5	1,000 tons TNT
6.0	6,300 tons TNT
6.5	31,600 tons TNT
7.0	200,000 tons TNT
7.5	1,000,000 tons TNT
8.0	6,300,000 tons TNT
8.5	31,600,000 tons TNT
9.0	200,000,000 tons TNT

Figure 5

2121. The magnitude is determined by instrumentation. The Modified Mercalli Scale (MMI) classifies earthquakes by describing their intensity. A scale is established with intensity ranges from I to XII (See Figure 6). Intensity scales are based upon written descriptions of observations or, in other words, a description of the physical effects of earthquakes. The lowest intensity ratings are based upon reactions, such as "felt indoors by few" as compared with the highest intensities which are measured by geologic effects such as "broad fissures in wet ground, numerous and extensive landslides, and major surface faulting." A general comparison between the two systems is that the Richter System is based upon measuring by instruments the magnitude of the energy released by the earthquake while the MMI Scale is based upon describing the effects of the earthquake based on visual observations and not by the use of instruments. Figures 7 and 8 denote and delimit the spatial location and times of major earthquakes in California.

FIGURE 6

MODIFIED MERCALLI SCALE* OF INTENSITY

I. Not felt. Marginal and long-period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favorably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing heavy trucks; or sensation of a jolt, like a ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frames creak.

V. Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken, knicknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D* cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle).

VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some towers, elevated tanks. Frame houses moved off foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; masonry B seriously damaged. (General damage to foundations.) Frames cracked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake foundations, sand craters.

X. Most masonry and frame structures destroyed with their foundations. Some wellbuilt wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud sifted horizontally on beaches and flat land. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines completely out of service.

XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

*Masonry A, B, C, D. To avoid ambiguity of language, the quality of masonry, brick or otherwise, is specified by the following lettering (which has no connection with the conventional Class A, B, C, construction).

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced or designed against horizontal force.

*1957 version, from "Elementary Seismology" by C. F. Richter, W. H. Freeman and Co., Inc., 1958.

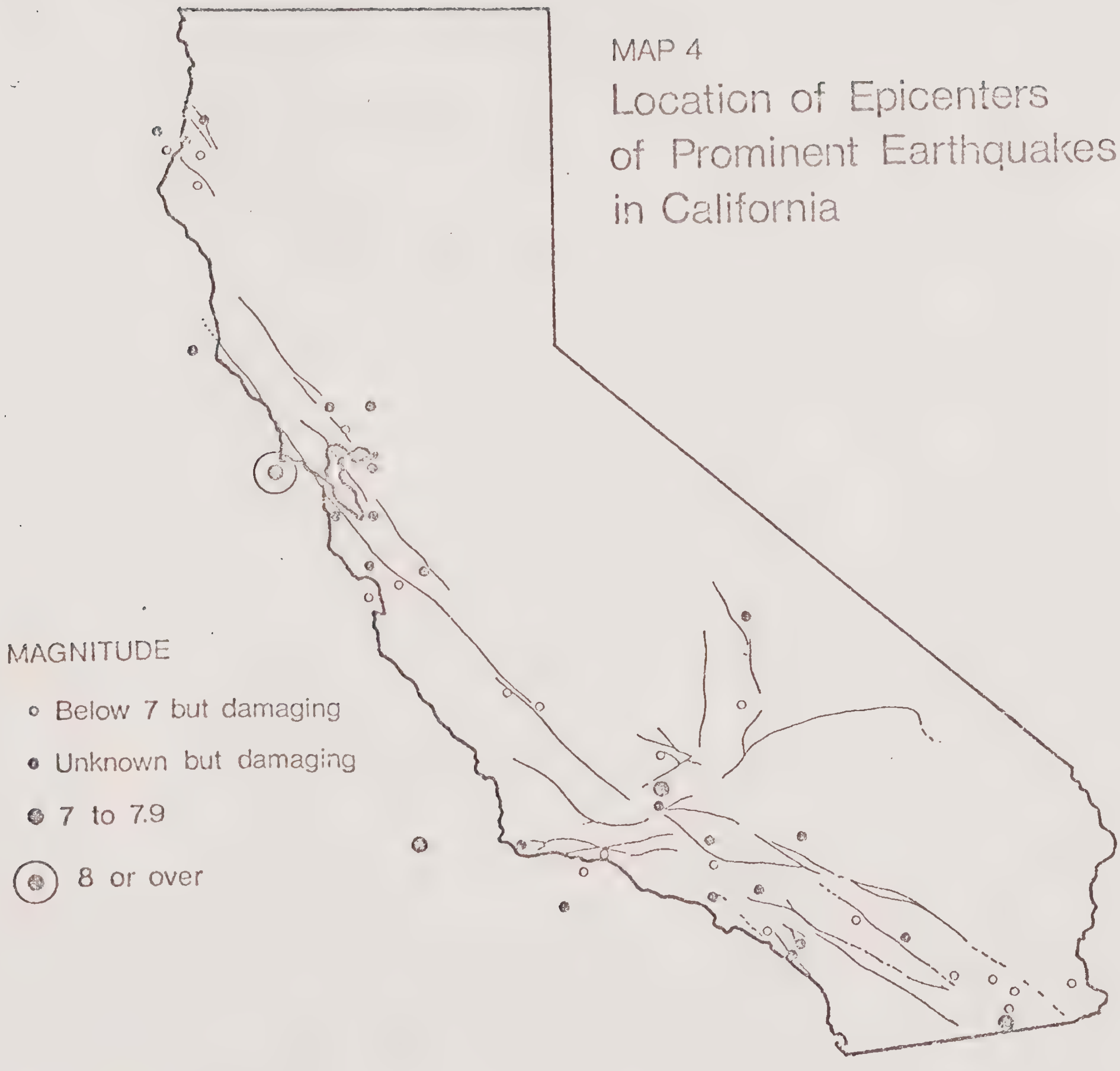

MAP 4
Location of Epicenters of Prominent Earthquakes in California
MAGNITUDE
Below 7 but damaging
Unknown but damaging
7 to 7.9
8 or over

FIGURE 7

PROMINENT EARTHQUAKES IN CALIFORNIA

DATE	REGION	RICHTER MAGNITUDE	MODIFIED MERCALLI INTENSITY
28 July 1769	Orange County, near Irvine	*	*
8 December 1812	Southern California	*	VIII-IX
21 December	Off coast of Southern California	*	X
10 June 1836	Hayward fault, Berkeley	*	IX-X
June 1838	San Francisco region, San Andreas fault	*	X
10 or 11 July 1855	Los Angeles County	*	VIII
9 January 1857	Fort Tejon-Carrizo Plain	Possibly 8	X-XI
26 November 1858	San Jose	*	VIII
November 1860	Humboldt Bay	*	VIII
3 July 1861	Near Livermore	*	VIII
1 October 1865	Fort Humboldt-Eureka area	*	VIII-IX
8 October	Sanata Cruz Mountains	*	VIII-IX
21 October 1868	Hayward	*	IX-X
26 March 1872	Near Lone Pine	Possibly 8+	X-XI
19 April 1892	Vacaville	*	IX
21 April	Winters	*	IX
4 April 1893	Northwest of Los Angeles	*	VIII-IX
20 June 1897	Near Hollister	*	VIII
14 April 1898	Mendocino area	*	VIII-IX
22 July 1899	San Bernardino County	*	VIII
25 December	San Jacinto-Hemet area	*	IX
27 and 31 July 1902	Santa Barbara County	*	VIII
18 April 1906	San Francisco region	8.3	XI
28 April	Brawley, Imperial Valley	6-6.9	VIII
28 October 1909	Humboldt County	6+	VIII
11 January 1915	Los Alamos	*	VIII
22 June	El Centro-Calexico-Mexicali area	6.25	VIII
21 April 1918	San Jacinto-Hemet area	6.8	IX
21 June 1920	Inglewood	*	VIII
10 March 1922	Cholame Valley	6.5	IX
29 June 1925	Santa Barbara area	6.3	VIII-IX
22 October 1926	Monterey Bay	6-6.9	VIII
20 August 1927	Humboldt Bay	*	VIII
4 November	West of Point Arguello	7.5	IX-X
25 February 1930	Westmorland	5.0	VIII
1 March	Brawley	4.5	VIII
6 June 1932	Humboldt County	6.4	VIII
10 March 1933	Near Long Beach	6.3	IX
7 June 1934	Parkfield	6.0	VIII
18 May 1940	Imperial Valley	7.1	X
30 June 1941	Santa Barbara-Carpinteria area	5.9	VIII
15 March 1946	North of Walker Pass	6.25	VIII
29 July 1950	Imperial Valley	5.5	VIII
21 July 1952	Arvin-Tehachapi	7.7	XI
22 August	Bakersfield	5.8	VIII
25 April 1954	East of Watsonville	5.25	VIII
21 December	Eureka	6.6	VII
12 September 1966	Truckee	6.6	VIII
8 April 1968	Northeast San Diego County	6.5	VII
1 October 1969	Santa Rosa	5.7	VII-VIII
9 February 1971	San Fernando	6.5	VIII-XI

*Information not available.

2200. SEISMIC EXPRESSION AND ITS IMPACT

2210. Crustal movement and faulting are evolutionary processes in the earth's geological history. When such processes happen in urban areas they create significant impacts on man and his activities. Consequently, it is important that there be an understanding of the different types of seismic activities and their impacts in order to develop an effective program of risk reduction.

2211. <u>Ground Shaking</u>

2212. Ground shaking is the major cause of damage in any seismic event. It is, in fact, the common denominator in all seismic activities. Ground shaking is the result of a surface wave movement of the materials of the outer part of the earth's crust. This motion is not constant since its direction and speed are directly related to the geological configuration of the crustal material. Surface topography can cause ground waves to compound and result in concentrations of energy. As ground waves pass from material (rock) to less dense material (alluvial or water saturated material) they reduce in velocity and increase in amplitude, thus, the more compacted/material has a tendency to filter out high frequency motion resulting in accentuated shaking for a longer period of time and at a lower frequency of vibration. Therefore, nearness to the area of initial rupture does not necessarily determine the intensity and duration of ground shaking that a building should be designed or constructed to withstand. The maximum frequency the overriding structure should be designed to withstand is therefore determined by the type, configuration, depth, and density of the underlying soil and rock. In summary, the degree of ground shaking is not entirely related to the proximity of the fault or epicenter but is also dependent on the composition of the underlying geologic conditions. Damage from ground shaking is caused by the transmission of frequency vibrations from the ground into the building. Every object has a response frequency, including buildings. When the building's response frequency is matched by the frequency vibrations from the building, vibration is amplified and the amount of damage created is related to the structural design, type of construction, height, and the intensity and duration of the ground motion. Buildings should be constructed to endure severe shaking with minimal structural damage and without collapsing. The building's systems (lighting, communication, stairwells, etc.) should also be designed to remain functional. The end result might be some damage to the buildings but no loss of life.

2213. <u>Surface Rupture</u>

2214. The greater the magnitude of an earthquake, the stronger the possibility of surface rupture. Ruptures normally happen at faults or fault traces, but it is possible for ruptures to occur at other locations. The rupture begins at the focus and may extend upward to the surface. Such surface penetration is not predictable, albeit there is a good probability that it will happen in an area where previous

ground rupture or cracking has occurred. Therefore, it is predictable that any structure located at the fault or surface rupture will experience serious damage. Consequently, building development should not be encouraged on or across known faults or fault traces.

2215. Ground Failure

2216. Ground failure is another category of geotechnic hazards. Although normally associated with seismicity, such hazards can be caused by other factors. The principal forms of seismically induced ground failure are: landslides (with associated rockfalls, mudflows, and lateral spreading), liquefaction, and subsidence. Landslides which are seismically induced can be catastrophic especially if the earthquake occurs during or following a period of heavy rainfall. This is particularly true where the slopes have been modified from their natural state. The possibility of landslides can be man-induced as a result of improper grading. Liquefaction is a specialized form of ground failure caused by earthquake ground motion. It is a "quickstand" condition in water-saturated unconsolidated, clay-free sands caused by hydraulic pressure (from ground motion) forcing apart ground material particles and forcing them into semi-liquid mixtures. The difference in states is comparable to the conversion of hard, wet beach sand into a soft plastic material of the consistency of wet concrete.

2217. Liquefaction occurs primarily in well-sorted granular non-cohesive sediments such as sands and non-plastic silts. Liquefaction problems are not likely to occur in plastic clay soils except where such deposits contain significant seams or lenses of sand or silt or perhaps in relatively rare occurrences of extra sensitive quick clays such as those found in eastern Canada and Norway. For saturated sands and silts, the development of liquefaction depends on:

(1) The intensity of ground shaking;
(2) The duration of ground shaking;
(3) The initial confining stress;
(4) The relative density; and
(5) The initial shear stress.

The probability of liquefaction occurring rises with increases in the intensity and duration of strong ground shaking. Liquefaction is generally considered unlikely during earthquakes having a Richter magnitude less than 5, which produce intensities no greater than V-VI on the Modified Mercalli Scale.

2218. The liquefaction potential of a soil is reduced with increases in confining pressure; confining pressures generally increase in proportion to depth. Since liquefaction is associated with saturated soils, liquefaction is more likely where the groundwater table is shallow (low confining stress) than where the groundwater table is deep (high confining stress). Liquefaction occurred at depths of 30 to 55 feet at the Jensen Filtration Plant during the 1971 San Fernando Earthquake, and depths of 40 to 80 feet beneath Anchorage during the 1964 Alaska Earthquake. Loose sands and silts are more

likely to liquefy than the same soils in a dense state. Because of the impervious and homogeneous nature of the fine-grained bay mud sediments which are found to the surface around much of San Francisco Bay, the probability of significant upward flow of water in areas where this mud sheet is continous laterally is minimal. If liquefaction occurs in or beneath a sloping mass, the entire mass may flow or translate laterally toward the unsupported side, resulting in a landslide. This landsliding associated with liquefaction can be subdivided into (1) flow slides with extensive lateral movement, and (2) landslides with limited lateral movement. In Borcherdt (1975), Youd concludes that "because of the generally small slopes, it is unlikely that this type of failure (flow slide) would occur on the broad alluvial plain surrounding San Francisco Bay." Documented cases occurred, however, during the 1906 Earthquake near Half Moon Bay and San Bruno Mountain. With perhaps some local exceptions, conditions conducive to quick ground failures do not generally exist within San Mateo County. The most common type of ground failure expected as a result of liquefaction in San Mateo County is lateral spreading landslides. This type of failure which consists of perhaps several feet of movement of a soil mass down a gentle slope with resulting cracks, fissures, and differential settlements within and near the margins of the slide mass.

2219. Tsunamis and Seiches

2220. Though traditionally called "tidal waves" in the West, tsunamis have nothing to do with tides; they are caused by earthquakes, volcanic eruptions, landslides, and man-made explosions near or under the sea. By way of analogy, like ripples caused by tossing a pebble into a pond, the tsunami rushes outward in widening circles. The distance from one wave to the next averages a hundred miles, but the waves are only a few feet high on the open sea. Unlike wind waves, the speed of a tsunami is determined by ocean depth. Deepwater tsunamis travel at more than 500 miles an hour. In shallow water areas, however, they rapidly slow down and pile up in awesome crests resulting in huge damage to coastal areas. These crests alternate with equally powerful troughs, which cause the sea to recede from shore for hundreds of yards. During a tsunami attack, currents charge in and out throwing debris onto coastal regions in alternating cycles. Seiches are earthquake-generated waves within enclosed or restricted bodies of water such as lakes and reservoirs. They might be compared to the sloshing of water in a bowl or bucket when it is shaken or jarred. The waves can be tens of feet high or more and have devastating effects on people and property within their reach. Dams and reservoirs can be overtopped and large volumes of water released to inundate or flood downstream development.

2221. Similar but even more catastrophic inundation can result during earthquakes from a dam failure or from large masses of earth that might be broken loose and slide into a reservoir or bay. The near failure of the Van Norman Reservoir during the 1971 San Fernando Earthquake resulted in the evacuation of 80,000 people that lived

below it. Although not generated by an earthquake, almost 3,000 lives were lost in Italy in 1963 when a huge landslide suddenly fell into a reservoir, sending up a wall of water and rocks 850 feet above reservoir level opposite the slide area and waves of water about 330 feet over the crest of the dam. The major risks of seiches in San Mateo County would be the Crystal Springs and San Andreas Dams.

2300. SEISMIC PREDICTION

2310. Earthquake prediction is still in its early stages of development. There are as many theories about the possible location, magnitude, and location of the next quake as there are experts studying them. Regardless of the level of study in earthquake prediction, the fact remains that there has been no definitive understanding of when or where earthquakes will occur. The only fact about earthquakes is that they will continue to occur.

2320. Precise earthquake predictions are almost impossible at this time, but it is possible to make some general projections. Geologic surveys and recordings of seismic activity over the years have resulted in the identification of a global strip where the major portion of the world's earthquakes occur. This strip is called the Circum-Pacific Seismic Belt and accounts for 80% of the world's earthquake activity (See Figure 9.) Since California is located within this earthquake belt, and earthquake frequency is greatest on the State's historically most active faults, it can be predicted that earthquakes will occur on the San Andreas, Hayward, Calaveras, and San Gregorio Faults. Faults which have been the source of great earthquakes (7.0 or greater on the Richter Scale) in the past can be expected to have earthquakes of the same magnitude in the future.

2330. As far as the time of the next quake is concerned, it can only be said that this is an extremely active seismic area. In the northern part of California, many seismeters constantly monitor seismic activity. It can only be concluded that earthquakes in California will continue to occur. As one seismic expert responded in respect to the possibility of another "major earthquake" occurring, he stated that "the chances of a major quake along the San Andreas fault in the foreseeable future are 100 percent." To demonstrate the degree of success in earthquake prediction, it should be pointed out what has occurred recently in the People's Republic of China. In 1974, the Chinese successfully predicted an earthquake in Haich'eng. Dr. Jack Evernden, a geophysicist with the United States Geological Survey, points out, however, that Haich'eng's highly publicized success was negated by a false alarm at Pan Shan, which forced hundreds of people to flee their homes in the Manchurian winter. And Chinese seismologists failed to foresee the 1976 Tangshan disaster that killed two-thirds of a million people. Such is the state of the art of seismic predictions.

CIRCUM-PACIFIC SEISMIC BELT

FIGURE 9

3000. *INTRODUCTION TO THE FOSTER CITY SITUATION*

3001. This section of the Seismic Safety Element will address the various geotechnical issues that confront the City of Foster City. Also, the various safety issues that are a result of the geotechnical issues will also be discussed. Briefly, the goetechnical issues for Foster City are: (1) strong ground shaking, (2) potential liquefaction, (3) inundation by tsunamis, (4) inundation from dam failure, and (5) possible subsidence. Specific safety issues for Foster City are confined to three major problems: access and circulation, acute medical care, and utility disruption.

3010. Background: Formation of Foster City

3011. Foster City is a "Planned Community," a community conceived, constructed and implemented on the basis of an organized program of development. The community was first established in 1960 as the Estero Municipal Improvement District by a special act of the State Legislature. The District consisted of about 2,591.6 acres of land controlled by T. Jack Foster and Sons and referred to at that time as Brewer Island. The primary function of the District was to provide the necessary funding for dredging, filling land for building site preparation, the acquisition and construction of both a water and sewer system, the construction of bridges, streets, storm drainage, lagoons and other facilities specified by the General Plan.

3012. In April, 1971, the City of Foster City was incorporated and although the District and City land areas are not altogether the same, for all practical purposes, they are generally recognized as being the same area. The City area does include about 9,700 acres of bay water. The incorporation also provided for the establishment of the Board of Directors of the District and the members of the City Council as being the same persons. The purpose of the incorporation was to make available, for the benefit of the citizens, certain State revenues and subventions such as sales tax, cigarette taxes, motor vehicle, in lieu taxes, etc., for public purposes. Among other things it also made it possible for the City to establish its own Planning Commission, adopt its own General Plan, provide for the establishment and enforcement of its own development regulations and generally provide for the control of its own destiny.

3100. LOCATION

3110. General Location Description

3111. Foster City is located on the mid-peninsula of the San Francisco Bay area. The City's planning area is bounded on the east by San Francisco Bay, on the west by Marina Lagoon and the City of San Mateo. The boundary in the north is in the Bay and to the south Belmont Slough and Redwood City.

3200. GEOLOGY

3201. Although the City contains an area of approximately 12,350 acres, over 9,725 acres are located in San Francisco Bay and Belmont Slough. This leaves a land area of about 2,620 acres. This land area of 2,620 acres was formerly referred to as Brewer Island. The Island was formed when the area, formerly a salt marsh, was diked off for use as salt ponds and dairy pasture land.

3202. The City rests on "young bay mud" with an overlying cover of artificial fill. Bay mud is predominately composed of saturated silty clays with a variable distribution of sands and silts. The soft muds vary in thickness - in the Redwood Shores, Bair Island area, soft muds are about 10 feet thick near the Bayshore Freeway, but about 60 feet thick near the eastern shore of Bair Island. It is well documented that there has been desiccation of the general area as a result of the diking off of the area about the turn of the century. The result of this has been that the top surface has achieved a moderate strength. The placing of hydraulic fill containing a high percentage of limestone (shells) has created a surface material with a relatively high shear strength.

3210. Pre-Existing Conditions of the Foster City Area

3211. Prior to construction of Foster City there were essentially three surface conditions within the proposed boundaries of the City. Two of these were reclaimed tidelands within perimeter dikes and the third was just outside the then existing dikes, in San Francisco Bay and its adjacent tidal lands. In this report the three surface conditions will be referred to as crusted areas, salt pond areas, and marsh areas. Within each area there were local irregularities formed by sloughs, dikes, and dredged ditches from which the dikes were constructed.

a. Crusted Areas (2,200 Acres Plus Possible Additive Areas):

Dikes to Elevation +8, mean sea level, formed of dredged bay mud presently existed on the periphery of the crusted areas. The land within the dikes was crossed by meandering sloughs estimated to be about 3 to 5 feet deep and 20 to 160 feet wide. The ditches parallel and adjacent to the dikes were about 3 to 4 feet deep and up to 150 feet wide. The average surface elevation was approximately zero, mean sea level, with local irregularities of plus or minus one foot. It was used primarily to raise hay and to graze livestock. The then existing ground surface would support medium wheel loads, such as applied by the truck-mounted drilling rig used in soil explorations, and moderate weight farm vehicles, except during periods of extended rainfall, when the surface becomes soft and slick.

b. Salt Pond Areas (550 Acres):

Dikes similar to the ones that surround the crusted areas also enclosed the salt pond areas. The land within the dikes was covered with approximately two feet of water at the time of the field research by Dames and Moore in 1960. However, the Dames

and Moore 1960 reports stated that the consultants felt that they expected the ground surface topography to be similar to the crusted areas with the exception of being much softer and lacking vegetation. The ground elevation at the Dames and Moore exploration borings indicated the bottom of the salt pond to be about 1.5 feet higher than the crusted area and at an average elevation of 1.5.

The salt ponds were used for concentrating saline waters of San Francisco Bay. The solutions were not saturated and no salt crystals have precipitated or otherwise formed on or within the underlying soils.

c. Marsh Areas (200 Acres):

The marsh areas were outside the diked areas and were within or below the tide range. Approximately 120 acres of this area was below low tide in the northwest corner of the site, north of the existing State Highway approach to the San Mateo Bridge, and had a surface elevation of about -5. The remainder of the marsh area was along the north side of Belmont Slough and had a surface elevation of about +3.5.

3220. Pre-Existing Subsurface Conditions

3221. The entire site was underlain by soft, compressible, organic silty clays, commonly called "Bay Mud." The depth of the mud encountered in the Dames and Moore 1960 exploration borings varied from 20 to 70 feet. The "Bay Mud" was underlain by firm clays and sands.

3222. The strength and compressibility characteristics of the upper five to six feet of "Bay Mud" was considerably different in the three main areas due to local effects of sloughs, ditches and dikes. In the marsh areas, neglecting the local effects, the mud was very weak and compressible at the surface and gradually increased in strength and decreased in compressibility with depth throughout its entire thickness. The bay mud below the upper five to six foot layer in the crusted areas and the salt pond areas was very similar to the bay mud at comparable depths in the marsh areas. In the crusted areas, the upper five to six feet had dried and shrunk, creating a relatively firm surface layer, much less compressible than the underlying soft mud. The upper soils in the salt pond area were submitted to drying and shrinking during the years when it was dry (1941 to 1951). The density, strength and compressibility were intermediate between the crusted and marsh areas. Dames and Moore stated in 1960 that if the salt ponds were emptied and permitted to dry, the surface would probably become similar to the crusted area after a period of four to eight months of dry weather. However, the upper five to six feet would still be softer and more compressible than the upper soils in the crusted area, and the surface elevation would still be about one foot above the crusted area. Similarly, if dikes were built around the marsh area and the area was drained and permitted to dry, the upper soils would shrink and strengthen.

3230. Foundation Factors Affecting Planned Development

3231. There were no soil conditions that would make development of the Foster City site impossible. However, two primary factors, "soil weakness" and "soil compressibility" would cause the development to be more difficult and somewhat more unusual than the "normal" community or industrial development.

3232. The relatively low strength of bay mud causes it to be unsatisfactory for direct support of buildings or streets. Instability may exist where abrupt differences in elevation occur, such as along dikes and channel slopes underlain by the weak bay mud. The relatively high compressibility of bay mud further complicated the development plans because of the continuing settlement that would occur subsequent to any load application. However, the proposed sand fill could be designed to offset the insufficient foundation supporting strength of bay; slopes could be designed that would be stable and would meet other planning criteria; settlements can be predicted within reasonable accuracy that would permit establishing construction grade that would settle to any desired final grade.

3233. The Dames and Moore 1960 report concluded that "the site can be developed for residential and light to medium industrial and commercial structures supported on shallow foundations within the proposed fill soils, and that such structures and surrounding land will settle approximately in accordance with rates and amounts that can be determined."

3240. Foster City Land Reclamation Project

3241. Since Brewer Island had been farmed for approximately sixty years, and about a third of the area had been used as evaporator ponds by Leslie Salt Company, a serious consideration had to be given to internal drainage problems. It was apparent from the start that the best method of disposing of rainfall within this area would be by utilizing a basin. This concept was then developed into a combination flood reservoir and recreation lagoon for sailing, comprising of approximately 240 acres. A Master Plan for the area was prepared and adopted by the Board of Supervisors of San Mateo County for the development of the 2,600 acre parcel. Of this, 1,300 acres were devoted to residential, approximately 150 to commercial, 310 to industrial, and 220 for schools and churches. Based upon this allocation, it was determined that there would be approximately 12,000 housing units which would accommodate an ultimate population of 38,000.

3242. Brewer Island soils presented a different problem than is normally found elsewhere, inasmuch as it was a crusted area overlying the bay mud. The average elevation of the land was at mean sea level, and was fully protected on its outer perimeter by large levees similar to those found within the Delta area.

3243. As it was necessary to raise the existing ground level, a number of studies were made relating to both dry and hydraulic fill placement. From these studies, it was determined that the hydraulic method

would be the most economical for transporting and compacting 20,000,000 cubic yards. Bids were taken for the land preparation and placement of this hydraulic fill, however, the Board of Directors rejected all of them as being too high. Subsequent studies showed that the District could construct its own special equipment in order to reduce these costs.

3244. In the Fall of 1961, plans were prepared for a new type of double-ladder dredge and the purchase of surplus barges from Great Salt Lake. The dredge hull was constructed from a Navy sea-going barge which was formerly used to haul supplies to Alaska. The hopper-bottom barges were acquired from the Southern Pacific Company, following completion of their rock-fill construction work on the new Lucian Cut-Off crossing Salt Lake.

3245. Prior to bringing the hydraulic fill into any one area it was necessary that all of the old existing sloughs be filled and compacted. Retaining dikes were constructed for control of the water such that all of the solid material would be deposited and the clear water would then flow to the water pump.

3246. In order to enhance the development and make the waterways of the lagoon systems usable for small boat traffic, concrete retaining walls were placed on the sixty-foot wide channels. Heavy rip-rap was utilized on the main lagoon shoreline in order to give adequate erosion protection.

3250. <u>Present Conditions in Foster City</u>

3251. The following table represents present land-use within the political boundaries of Foster City:

TABLE "A"
EXISTING LAND USE
FEBRUARY 26, 1979

Land Use	Developed	Vacant	Total	Projected 1990 Developed	1960 Planned
Residential	951.1	185.8	1136.9	1219.7*	1360
Commercial	70.8	149.7	220.5	276.4*	150
Industrial	49.6	366.0	415.6	138.1*	310
Schools	26.2	81.6	107.8	58.8	180
Churches	13.4	5.1	18.5	18.5	40
Parks	61.1	61.2	122.3	127.2	
					230
Lagoon	185.0	--	185.0	185.0	
Bay Land	20.0	--	20.0	206.9	0
Municipal	20.8	4.2	25.0	25.0	30
Streets/Highways	340.0	--	340.0	336.0	300
TOTAL	1,738.0	853.6	2,591.6	2,591.6	2,600

*Includes future public street right-of-way (approximately 21.9-acre residential and 15-acre commercial/industrial).

Source: Foster City Public Works Department

3300. GEOTECHNIC ISSUES FOR FOSTER CITY

3310. Liquefaction

3311. During the course of Foster City's development, there have been questions raised concerning the potential for liquefaction of Bay Muds due to the occurrence of an earthquake. By way of definition, liquefaction is a seismically induced ground failure, occurring when a saturated, relatively loose granular soil or alluvial deposit is temporarily transformed to a liquefied state by a shock or stress, such as an earthquake of moderate to high intensity. Liquefaction occurs primarily in granular non-cohesive soils such as sands and non-plastic silts. Current opinion is that liquefaction problems are not likely to occur in plastic clay soils except where such deposits contain significant seams or lenses of sand or silt or perhaps in the case of extra sensitive quicksands found in Canada and Norway.

3312. For saturated sands and silts, the development of liquefaction depends on: (1) the intensity of ground shaking; (2) the duration of ground shaking; (3) the initial confining stress; (4) the relative density; and (5) the initial shear stress. The probability of liquefaction occurring rises with increases in the intensity and duration of strong ground shaking (which is related to the earthquake magnitude). Liquefaction is generally considered unlikely during earthquakes having a Richter Magnitude less than about 5.

3313. "Subsurface data available for the Foster City area indicates the apparent absence of a potentially liquefiable, continuous sheet of sand and gravel within the Bay Mud deposits" (Draft Seismic Safety/ Safety Element, 1975). In the 1975 Dames and Moore Seismic & Safety Elements of the General Plan for San Mateo County, these consultants stated that "the Bay Mud" sediments in San Mateo County are composed almost exclusively of silty clay, but also contain occasional lenses of sand and silt (principally in the area of San Bruno Shoals). Work by consultants in the Redwood Shores area indicates little or no loss in strength during dynamic loading for silty clay samples of Bay Mud. According to these same consultants, no significant amounts of sand lenses within the Bay Mud were disclosed by the more than 250 borings made on the Redwood Shores area. "The results of dynamic triaxil analysis tests on samples of sand and gravel from strata beneath the Bay Mud in the Redwood Shore areas indicate that these deeper lenses of granular sediments should remain relatively stable under seismic shaking." Moreover, the 1975 Dames and Moore Report goes on to state that "the characteristics of the Bay Mud and recent alluvium beneath Foster City may be similar to those of the Redwood Shores area," and hence may have similar "low" liquefaction potential.

3314. However, there are experts who have questioned the entire issue of liquefaction of Bay Mud. One of these is Richard H. Jahns, Professor of Geology, Stanford University. In a letter dated October 11, 1975 to the San Mateo County Planning Commission, Jahns states that (speaking of the 1975 Dames and Moore Report) "The phenomenon of liquefaction,

much emphasized throughout the report, is identified as a widespread and serious hazard in the context of Bay Mud, in part by implication and in part by direct statements. That this almost certainly is incorrect is indicated by the known behavior of Bay Mud during major historic earthquakes, and by a substantial body of data on the nature and distribution of component sedimentary materials in the mud units."

3315. In a letter dated September 15, 1975, and addressed to the San Mateo County Planning Commission, William W. Moore of Dames and Moore states "This phenomenon '(Liquefaction)' is possible only in saturated granular soils (i.e., fine to medium coarse sands) and cannot occur in cohesive, 'impervious' soils. The San Francisco Bay Area contains very limited deposits of liquefiable soils, and certainly the so-called 'Bay Muds' are not in this category." Moreover, at a meeting entitled "Convening of Experts," held February 9, 1976 to discuss the San Mateo County Seismic Safety/Safety Element, the minutes of that meeting offer an insight into the issue of liquefaction in the "Bay Muds." At that meeting, Dr. Harry Seed of the University of California, Berkeley spoke about the issue of liquefaction of the "Bay Muds": he indicated that "Bay Mud does not liquefy, but rather the presence of sand lenses provides a basis for liquefaction potential. If Bay Mud is perfectly level, then a dampening syndrome is experienced when ground shaking occurs. In order for ground failure from liquefaction to occur, the sand lenses must be near a sloping surface."

3316. In an Environmental Impact Report prepared by Woodward-Envicon, Inc. in October, 1974 for the Redwood City Planning Department, the consultant firm took the following attitude concerning the issue of liquefaction: "There is no evidence, either from historic records of conditions during earlier earthquakes, or from the recent exploratory borings and soil tests, which suggests to the Board that the bay muds at the site are of such composition as to be sensitive to liquefaction effects. To the contrary, dynamic tests on undisturbed samples have indicated little or no loss of strength under pulsating loading."

3317. Mobil Oil Estates (Redwood) Limited in September of 1975 made what can be termed critical comments of the then proposed San Mateo County Seismic Safety/Safety Element over the issue of liquefaction potential in the Redwood Shores area. Mobil Estates was taking the position that the individuals responsible for the writing of the San Mateo County Seismic Safety/Safety Element were disregarding the $750,000 worth of seismic and soils studies that had been conducted concerning the Redwood Shores development. While Mobil Estates took the position that its comments were restricted to Redwood Shores, Mobil Estates did state their remarks could be applied to other areas of the County east of the Bayshore Freeway. A report by the consultant firm of Cooper-Clark & Associates summarized Mobil Estate's opinion of the issue of liquefaction in the Redwood Shores area: "Due to the general absence of significant lenses of sand, it is our opinion that the liquefaction potential within bay mud areas in San Mateo County and particularly in Redwood City is, with some exceptions, low to non-existent. This opinion is in direct contradiction to the recommendations presented on the Geotechnical Hazards Synthesis Map, and most of the discussion and recommendation presented in the text of the Draft Seismic and Safety Element" (Cooper-Clark & Associates, page 3, paragraph 3).

3318. Even though ground failures or foundation failures would not always result from liquefaction of sand lenses, dynamic compaction of such sand lenses would result in settlements at the ground surface. Assuming that compaction of sand lenses were to occur due to liquefaction, the resulting settlements would not necessarily be immediately reflected at the ground surface. If the sand layers were located at depth in the bay mud, settlement at the ground surface would occur only as the water in the voids created by the settlement of the sand could drain through the bay mud. Since the bay mud is very impermeable, on the order of 10^{-6} to 10^{-8} cm/sec or less, it could take many years before this water could drain from the voids and result in settlement at the ground surface. Also, the amount of settlement due to complete liquefaction of a sand lens would be in the range of from one percent to, at the most, three percent of the thickness of the sand deposit. Since the sand deposits within the bay mud soils are usually thin, the amount of ground surface settlement should be minor (Cooper-Clark & Associates, "Review and Comments, Draft Seismic and Safety Elements of the General Plan, San Mateo County, California," page 4).

3319. In summary, it would appear that a number of conclusions can be reached regarding the potential of liquefaction in the City of Foster City: (1) Foster City is built over "Bay Muds," with an apparent absence of potentially liquefiable deposits (Dames and Moore, 1969); (2) that Redwood Shores and Foster City share the same "Bay Muds" (Dames and Moore, 1975); (3) That there is disagreement over those who think that there is liquefaction potential in the "Bay Muds" (Dames and Moore, 1975, San Mateo County Seismic Safety/Safety Element) and those who feel that there is little, if any potential for liquefaction (Professor R. H. Jahns, William W. Moore of Dames and Moore, Dr. Henry Seed, Woodward-Envicon, Inc., and Mobil Oil Estates); and (4) in general, liquefaction potential is low at worst and non-existent at best.

3320. Tsunamis

3321. Introduction

a. One of the major issues presented in the San Mateo County Seismic and Safety Element of 1975 for the City of Foster City was the issue of tsunamis. In this section of the Foster City Seismic/ Safety Element, consideration is directed towards the issue of tsunamis for the City of Foster City.

3322. Nature of Tsunamis

a. Tsunamis accompany only those earthquakes whose epicenters are at shallow depths, less than 100 km, beneath the ocean or close to the shore; most tsunamis are generated by abrupt deformation of the sea bottom, either by fault displacement or more general deformations caused by earthquakes, including deformation due to submarine volcanic explosions or landslides. Tsunami magnitude can be estimated from the generation mechanism of the tsunamis, the dimensions of the area of tsunami origin, the speed and amount of displacement, and the water depth at the tsunami's source. The dimensions and degree of crustal deformation of an ocean bottom

are closely related to the earthquake magnitude, its focal depth, and the focal mechanism of the earthquake. Further, the area of tsunami origin is closely related to the area deformed by the earthquake and is approximately equal to the area of the aftershock activity.

b. Sudden deformation of a sea bottom is generally caused by a main shock. By the change in stress or strain due to this deformation, aftershocks are caused. Consequently, it is determined that an aftershock does not partake in the production of the deformation of the sea bottom. Since a tsunami results from sea bottom deformations, which an aftershock does not produce, aftershocks are not accompanied by tsunamis (Iida, 1970, pp. 16-17).

3323. Tsunami Warning System

a. In 1948, the Seismic Sea Wave Warning System was organized with four seismological observatories and nine tide stations. These initial seismic stations were College, Sitka, Tucson, and Honolulu; the tide stations were located at Attu, Adak, Dutch Harbor, Sitka, Palmyra, Midway, Johnston Island, Hilo, and Honolulu. All but one of these participating stations, the Palmyra tide station, are still part of the Warning System. In 1948, the primary objective of the Warning System was to supply tsunami-warning information to civil authorities in Hawaii and to various military bases throughout the Pacific.

b. From this rather modest start, the Tsunami Warning System has increased considerably both in number of participants and in scope of warning responsibility. The seismic stations are now twenty-one and the number of tide stations has increased to forty-one (On the Pacific Coast of North America there are a total of twenty-one seismic and tide stations.). In California, there are tide stations at Crescent City, La Jolla and San Francisco, and seismic stations at Berkeley and Pasadena. The Tsunami Warning System will eventually be expanded to about 30 seismic stations and about 120 tide stations. When the Tsunami Warning System is expanded to this level, complete tsunami warning will become a reality in the Pacific (Murphy, L.M. and Eppley, R. A., 1970, pp. 261-269).

3324. Foster City Situation

a. The San Mateo County Seismic and Safety Element states that according to Ritter and Dupre (1972) (Maps showing Areas of Potential Inundation by Tsunamis in the San Francisco Bay Region, California, United States Geological Survey Map MF-480), "...inundation of Foster City by tsunamis is possible, but highly unlikely." On the Geotechnical Hazard Synthesis Map nearly all of Foster City is indicated as subject to flood hazard from tsunamis.

b. Charles L. Nichols, a partner in the consultant firm of Dames and Moore, in 1978, contacted William R. Dupre (currently associated with the Department of Geology, University of Houston) concerning the assumptions made in compiling USGS Map MF-480. Dr. Dupre stated that the following assumptions were established in developing Map MF-480:

1) All dikes existing in 1972 would hold in the effect of a tsunami;
2) No new dikes would be built, and dikes existing in 1972 would not be increased in height;
3) The tsunami under consideration in Map MF-480 would occur during a time of mean high water; and
4) Wind generated tides were not considered in any calculations.

c. Moreover, during his field work, Dr. Dupre noted that dikes in the southern part of Foster City were lower than the other dikes protecting the area. It was assumed that flooding of Foster City due to a tsunami would be by overtopping of the lower southern dikes (Since 1972, some southern dikes have been raised.). Also, in retrospect, Dr. Dupre expressed the belief that the assumption of a 20-foot tsunami at the Golden Gate coupled with a period of mean high water is perhaps too extreme.

d. In his September, 1978 letter, Nichols found no basis for the 20-foot tsunami, other than reference on Page 35 of Volume 2 of a 20-foot wave at Crescent City resulting from the 1964 Alaska Earthquake. Also, Page 36 of Volume 2 states "A subsequent report for the Federal Flood Insurance Program indicates a lesser runup in the Bay."

e. Nichols also made reference to a report by Marine Advisers, Inc., dated August 31, 1965, which is included in the "Report of Seismic Investigation for Redwood City General Improvement District 1-64, September 1965" by Daniel, Mann, Johnson and Mendenhall and Dames and Moore.

f. The study included research of tsunamis affecting the California Coast dating to 1812. In comparing the sensitivity of San Francisco with Crescent City, the report stated in part that "Examination of San Francisco (Presidio) tide gage records for the five most recent great tsunamis from remote sources (Aleutian Islands, 1946; Kamchatka, 1952; Aleutian Islands, 1957; Chile, 1960; Gulf of Alaska, 1964) gives no indication that this location is sensitive to remote tsunamis, the maximum fall or rise in each case being in order of 30-40% of that for Crescent City and falling closer to known insensitive locations (for example, Los Angeles Harbor and San Diego). Alameda Air Station tide gage records are available for the last two events and, as may be expected from physical considerations, show somewhat smaller tsunami heights than at the Presidio. At Redwood City, the same two events were smaller yet. These two cases are perhaps the largest distant tsunami events in the history of California, and certainly the largest in recent times. We conclude that there is ample indication that at Redwood City the greatest known remote tsunamis would not exceed the mean tidal range in (trough-to-crest) height, i.e., approximately six feet."

g. With reference to locally generated tsunamis, the report states "The history of California is marked by the almost total absence of local tsunamis. The 1927 Point Arguello earthquake (magnitude 7.25) raised a tsunami reported up to 6 feet in height in the immediate vicinity; it is the largest authenticated such event."

h. The Report of Seismic Investigation was extensively reviewed by the Seismic Advisory Board, City of Redwood City, composed of well-known authorities. In this report to the Redwood City Council, dated April 5, 1972, it was stated that:

> "Tsunami Effects
>
> The historic record of tsunami effects in San Francisco Bay, which includes information newly available during the past six years, indicates that the bay has been significantly influenced only by tsunamis representing distant earthquakes. There is no record of tsunamis generated by California quakes. Tide gage records show that tsunamis entering the Golden Gate are decreased considerably as they propagate toward the south end of the bay; their amplitudes are reduced at least 75 percent by the time they reach Redwood Shores. This damping effect, taken together with the fact that the greatest tsunami yet recorded at the Golden Gate was only three feet, makes it very unlikely that the 3.5 foot freeboard (above maximum astronomical tide) at the bayfront levees of Redwood Shores would ever be overtopped by tsunami action."

i. In conclusion, Nichols states that "In view of the above, although we recognize that the possibility of tsunami occurrence cannot be eliminated, and it is proper to refer to it in the report, we question the use of the flooding symbol, particularly over all of Foster City. The San Mateo County report refers to inundation as highly unlikely. If overtopping did occur, flooding may be limited to the area near the dikes, or between the dikes and the interior lagoons. The map indicates Foster City as subject to more widespread flooding than other bayside communities. We do not believe there is adequate basis for this."

j. To place the possibility of a tsunami striking Foster City in proper perspective, Arthur M. Stout, at the time a member of the Foster City Planning Department, used the following logic to place in perspective the effect of a tsunami striking the City:

> "The normal tide range, using Foster City datum, is 96.095 to 102.334 feet and the mean tide elevation is taken at 100 feet. The minimum dike elevation is 108 feet, which means that minimum height sections could be at or near overtopping, providing that the tsunami occurs at the time the tide exceeds 102 feet. The probability of occurrence of this event is approximately 1 in 423,000.
>
> The highest tide is 106.8 feet. The probability of this event occurring with the 6 foot tsunami wave is approximately 1 in 256,000. This is based on the estimate that the maximum duration of overtopping is 6.8 hours in a year of 8,760 hours with 200 years as the mean time between tsunamis."

In other words, if a tsunami occurred every 200 years, or for that matter every year, there is only one chance in 1280 that it would happen at a time when the tide would permit overtopping the dike.

k. On June 8, 1976, Stout once again pointed out the amount of damage that might occur from a tsunami coming from the North Bay. In part he said, that assuming a five-foot tidal wave in the Bay at Foster City on an estimated 200-year recurrence interval, overtopping of the north levee (crest elevation 109.8) could only occur if the tide elevation was in excess of 104.8. A tidal wave approaching Foster City from the north will have its most severe impact upon the north levee. A tidal wave will shear along the east levee (crest elevation 109.0). However, the San Mateo-Hayward Bridge and the County Fishing Pier will dissipate much of the energy of the wave. Belmont Slough will experience some effect of the wave but because it is protected by the projection of Brewer's Island into the Bay, a five-foot wave could not enter the Slough. No general inundation of Foster City would occur even if the tide elevation was in excess of 104.8 feet because only that amount of water in the wave crest above the top of the levee would produce minor flooding.

3325. Seiches

a. Seiches are earthquake-generated waves within enclosed or restricted bodies of water such as lakes and reservoirs. They might be likened to the sloshing of water in a bowl or bucket when it is shaken or jarred. The waves can be tens of feet high or more and cause devastating effects on people and property within their reach. Dams and reservoirs can be overtopped and large volumes of water released to inundate or flood downstream.

b. Similar but even more catastrophic inundation can result during earthquakes from a dam failure or from large masses of earth that might be broken loose and slide into a reservoir or bay. For the City of Foster City, the seiche issue within the political boundaries of the City is regarded as being virtually negligible (Dames and Moore, 1976, Vol. 2, p. 23).

3330. Dam Inundation

3331. In November of 1974, Engineering Decision Analysis Company, Inc. (EDAC) presented to San Mateo County and participating cities a draft report dealing with seismic hazards in the County of San Mateo. One of the subjects that is addressed by this report relates to the condition of dams in the County. Some of the comments made by this report are especially appropriate to this document.

3332. The first generalization that EDAC made concerns the possibility of damage to a dam from the occurrence of an earthquake. If a fault displacement of the right character and of sufficient magnitude is found at the dam site, it is possible for any dam to fail. There are no records of such failures even though some dams are located on known faults. Crystal Springs Dam was undamaged in 1906 despite its close proximity to the San Andreas Fault.

3333. As with buildings, old inadequately designed and constructed earth dams have had a poor earthquake record. The 1971 San Fernando experience with two hydraulic fill earth dams, in which approximately 12,000 residents downstream of the dams were evacuated while the reservoirs were drained, has resulted in a general review of all similar dams. Studies by Seed and Idriss indicate that failure through liquefaction requires the proper combination of construction and site conditions, intensity of ground shaking, and duration of severe shaking. Thus, despite the San Fernando experience, hydraulic filled earth dams should receive extensive study before being classed as unsafe. Concrete arch and gravity type dams have had an excellent service record providing the foundation conditions are adequate. Research has indicated the likely problem areas with such structures. Rolled fill earth and rock fill dams have performed well in earthquakes although the experience has not been extensive. These soil structures can be designed to have a high level of resilience and resistance to failure even with poor foundation conditions.

3334. Turning to the 1976 San Mateo County Seismic/Seismic Safety report, Volume 1 states that "Inundation of Foster City from the failure of San Andreas and Crystal Springs dams is a possibility, although remote." It is further stated "...since the dam inundation map used as the data base in this study is oriented toward emergency preparedness planning, without qualifications as to depth, velocity of water, duration of inundation, or even the probability of such a maximum occurrence, planning considerations for such an event cannot reasonably be applied without more substantial study and data." Since the San Mateo County Seismic/Seismic Safety report is concerned with the possibility of inundation of Foster City by failure of the Crystal Springs and the San Andreas Dams, however remote, attention should be directed towards the condition of these respective dams.

3335. First, in respect to the Upper Crystal Springs Dam, it now serves as a roadway across Crystal Springs Reservoir. The water level is being maintained at the same level on both sides of the embankment. Therefore, this structure is not considered to be a dam and is not subject to State jurisdiction. Lower Crystal Springs Dam is a 131-foot high curved concrete gravity dam which was constructed about 1890. This dam was originally designed to be approximately 43 feet higher than its present height. According to the records of the San Francisco Water Department, the dam was in operation and impounding water at the time of the April 10, 1906 earthquake. A picture dated May 17, 1906 shows the Crystal Springs Reservoir to be nearly full. Although this dam is quite old, it is still considered to be in excellent condition. Since the designers originally contemplated that the dam would be considerably higher, the mass and design configuration of the structure is significantly more conservative than it would normally be for a dam of this height. The San Andreas rift zone is located about 1,000 feet southwest of the dam. The San Francisco Water Department takes the position that any future movement would most likely occur along the recent trace of the San Andreas Fault; however, it is recognized that there is the possibility of a new break occurring. If the rupture occurs closer to the dam, the San Francisco Water Department feels that the dynamic forces to which the dam would be subjected would not be significantly different.

3336. The art and science of earthquake engineering for dams has progressed considerably in recent years. This involves advances in analytical techniques for response of concrete dams to seismic forces and the utilization of electronic computers. Despite this progress, it must be recognized that dynamic analysis for concrete dams is imperfect. Since the new techniques available for analyzing the seismic stability of dams need further development, the San Francisco Water Department takes the position that the test of present methods analysis, the past performance including the fact that Lower Crystal Springs Dam withstood the 1906 Earthquake with no apparent damage and remains in good condition is sufficient to make a reasonable judgement as to its adequate safety.

3337. The San Andreas Dam is a 107-foot high earth fill dam which was constructed about 1870. The San Andreas Fault passes just east of the east end of the dam. The dam is a compacted earth fill embankment with a puddled core. This dam was also operating and impounding water at the time of the April 18, 1906 Earthquake. A picture dated May 20, 1906 shows the reservoir level to be an estimated 20 feet below the top of the dam. A sophisticated method for determining the seismic stability of earth fill dams using this finite element procedure is by performing a dynamic analysis. While this method is relatively new and the input information is generally limited, it is considered to be the best method available for analyzing the dynamic stability of earth fill dams. This method will undoubtedly be improved upon as more information becomes available.

3338. A thorough investigation of the Upper and Lower San Fernando Dams, which were damaged by liquefaction during the February 9, 1971 Earthquake has been made. These structures were hydraulic fill type dams. As a result of this investigation, the Division of Safety of Dams requires that a dynamic analysis be made of all hydraulic fill dams. This program will be enlarged to include other important earth fill dams, such as San Andreas Dam. At the present time (August, 1974), it is interesting to note that San Andreas Dam is not being considered for reevaluation using comprehensive dynamic analysis. The reason for this is that the materials in San Andreas Dam are cohesive clays that are not particularly susceptible to liquefaction, the hazard potential of a failure is reduced because of Lower Crystal Springs being just below, and the fact that it withstood the 1906 Earthquake. These dams are inspected twice a year by registered engineers from the Division of Safety of Dams, accompanied by representatives of the San Francisco Water Department. The San Francisco Water Department engineers also perform inspections more often.

3339. Both San Andreas and Lower Crystal Springs Dams are considered to have an adequate margin of safety and are currently certified for full use based on periodic inspection and review of surveillance data (Dukleth, G. W., letter of August 4, 1974 to James F. Halcomb, Superintendent, Hillsborough City School District, Hillsborough, California). In September of 1978, Charles Nichols of Dames and Moore contacted a Mr. Patel of the San Francisco Water Department concerning the flooding limits shown on the Geotechnical Hazard Synthesis Map of the Seismic Safety/Safety Element. Mr. Patel provided Dames and Moore with the Inundation Map of Crystal Springs

Dam, Sheet 2 of September 2, 1972, which was prepared by the San Francisco Water Department. This map indicates the limits of flooding and the total elapsed time between initial dam failure and the arrival of water at various points. The limits are similar to those shown on the Geotechnical Hazard Synthesis Maps.

3340. Ground Shaking and Associated Hazards

3341. Since the Seismic Safety Element is a mandatory component of the General Plan, it follows that the examination of the guideline formulated by the California State Council of Intergovenmental Relations should be examined. Essentially, this body recommended the following action: The identification and appraisal of seismic hazards such as susceptibility to surface rupture from faulting, to ground shaking, to ground failures and to the effect of seismically induced waves. Much of the recommendations presented by the California State Council of Intergovernmental Relations were incorporated in the State Code dealing with Seismic Safety (Sections 65302 and 65302.1).

3342. General Overview

3343. Thousands of earthquake shocks occur in California every year. Of these, nearly 500 are large enough to be felt. During the past 50 years, California has experienced an average of destructive magnitude per year. In the Bay Area, earthquakes of destructive magnitude can be expected to come primarily from movement along two faults, the San Andreas Fault and the Hayward Fault. Since 1800 there have been five major earthquakes in the Bay Area caused by movement along these faults. In 1836, a major shock occurred on the Hayward Fault and fissures opened for a distance of 45 miles between San Pablo and Mission San Jose. In 1838, a major earthquake along the San Andreas Fault was accompanied by surface breakage between San Francisco and Santa Clara. Another damaging shock in 1865 apparently was centered on the San Andreas Fault in the Santa Cruz Mountains. In 1868, the great Hayward Earthquake (magnitude near 7) resulted from movement along the Hayward Fault; cracks and fissures opened for a distance of 20 miles between San Leandro and Warm Springs. The San Francisco Earthquake of 1906 (magnitude 8.3) resulted in ground breakings along the San Andreas Fault for a distance of 270 miles from southern Humboldt County to San Juan Bautista; a maximum horizontal displacement of 21 feet occurred near the head of Tomales Bay (Dalrymple and Lamphere, 1964, p.3).

3344. The foregoing tabulation of the largest Bay Area earthquakes shows that these earthquakes are related to known major geologically active faults. In general, in the Western United States, large earthquakes with large surface ruptures can be related to clearly defined geologic faults. Geologists cannot guarantee that there are no major faults under San Francisco Bay, except possibly for the northern extension of the Hayward and Calaveras Faults (Steinbrugge, 1968, pp. 8-9).

3345. Specific Review of the San Mateo County Situation

3346. The major structural feature of San Mateo County is the San Andreas Fault Zone. The San Andreas Rift Valley is situated along the fault zone, and is composed of numerous, intertwining branches of the fault, forming a zone of sheared rock up to a mile in width. The most recent (1906) trace of the fault occurs within this zone. The San Andreas Fault has shifted position at some time in the past. The ancestral San Andreas Fault and Pilarcitos Fault, separate the granitic Point Reyes-Montara block on the west, from the Franciscan San Francisco-Marin block, on the east.

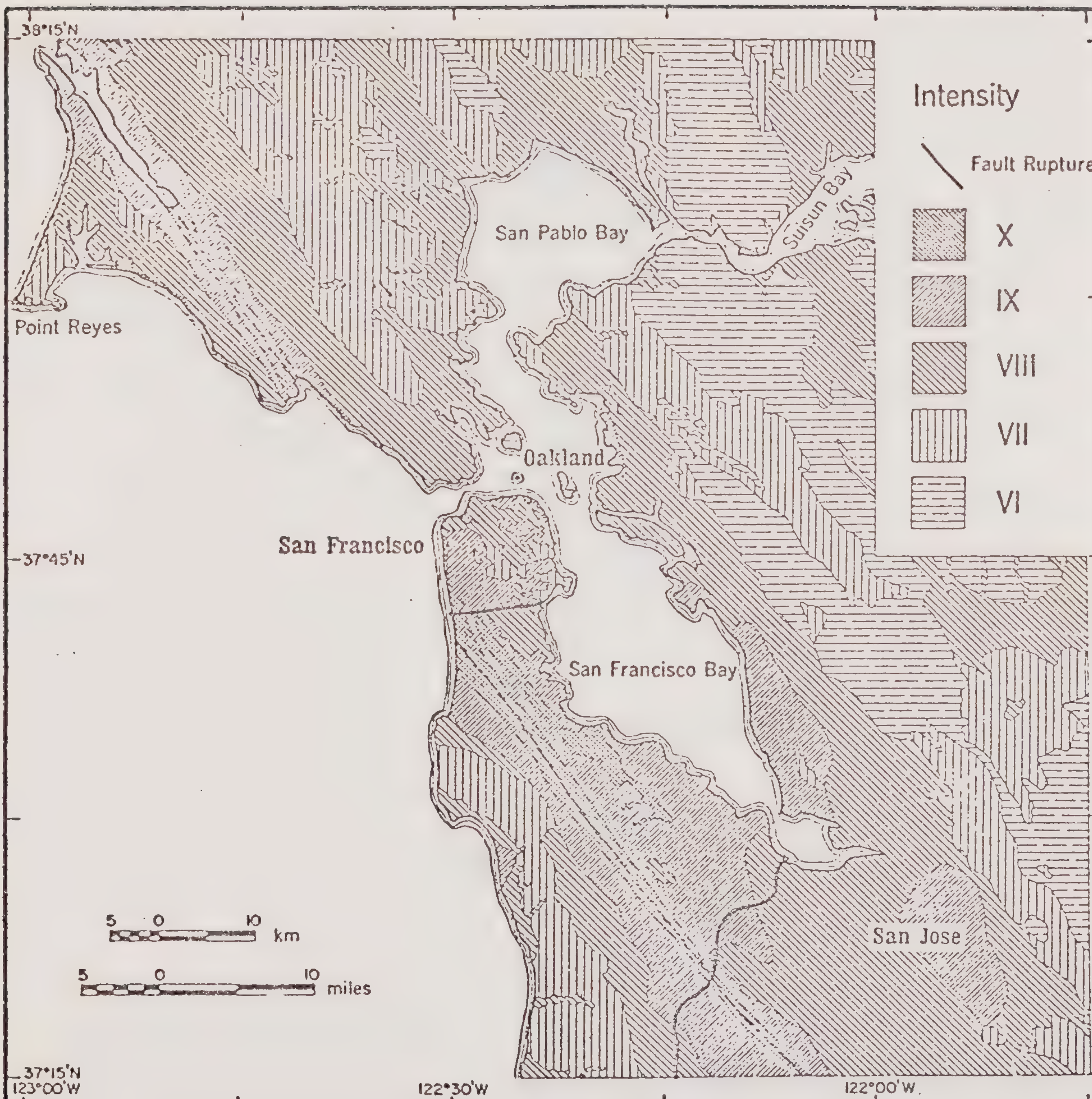
3347. The structure within both the Point Reyes-Montara and the San Francisco-Marin blocks is very complex. East of the San Andreas and Pilarcitos Faults is a complex assemblage of Franciscan and Teriary sedimentary rocks, highly folded and faulted. West of these faults, cretaceous and younger sediments overlie granitic rocks, both at normal depositional and as faulted contacts. The San Andreas Fault is a right-lateral strike-slip fault, that is, the opposite side of the fault from observer is being displaced relatively to the right. The Seal Cove and San Gregorio Faults show normal (block over fault moves down relative to underlying block) movement, and possibly strike-slip movement as well.

3348. The significance of the Serra Fault is that it is a thrust fault (block above fault plan moves up relative to lower block). Accelerations recorded during the San Fernando Earthquake of 1971 (where the relative movement was thrusting) were significantly higher than ever recorded before. It is not known whether actual ground rupture must occur in order for significant accelerations to occur from a thrust fault, but it does appear that the important component not previously considered is vertical acceleration. Figures 10, 11, and 12 denote the spatial spread of earthquakes of a Richter magnitude of 8.3, 7 and 6, respectively.

3349. Three different sources of damage are found with earthquakes; permanent ground displacement, ground stretching and shortening deformation, and ground shaking. Permanent ground displacement includes first, the direct effects of faulting in which the facility is subject to permanent direct differential ground distortion and, second, the permanent cracking, diffential subsidence of elevation, stretching and shrinkage so evident in the 1971 San Fernando Earthquake. It is possible to arrive at some general conclusions for San Mateo County based on the Geological Survey data:

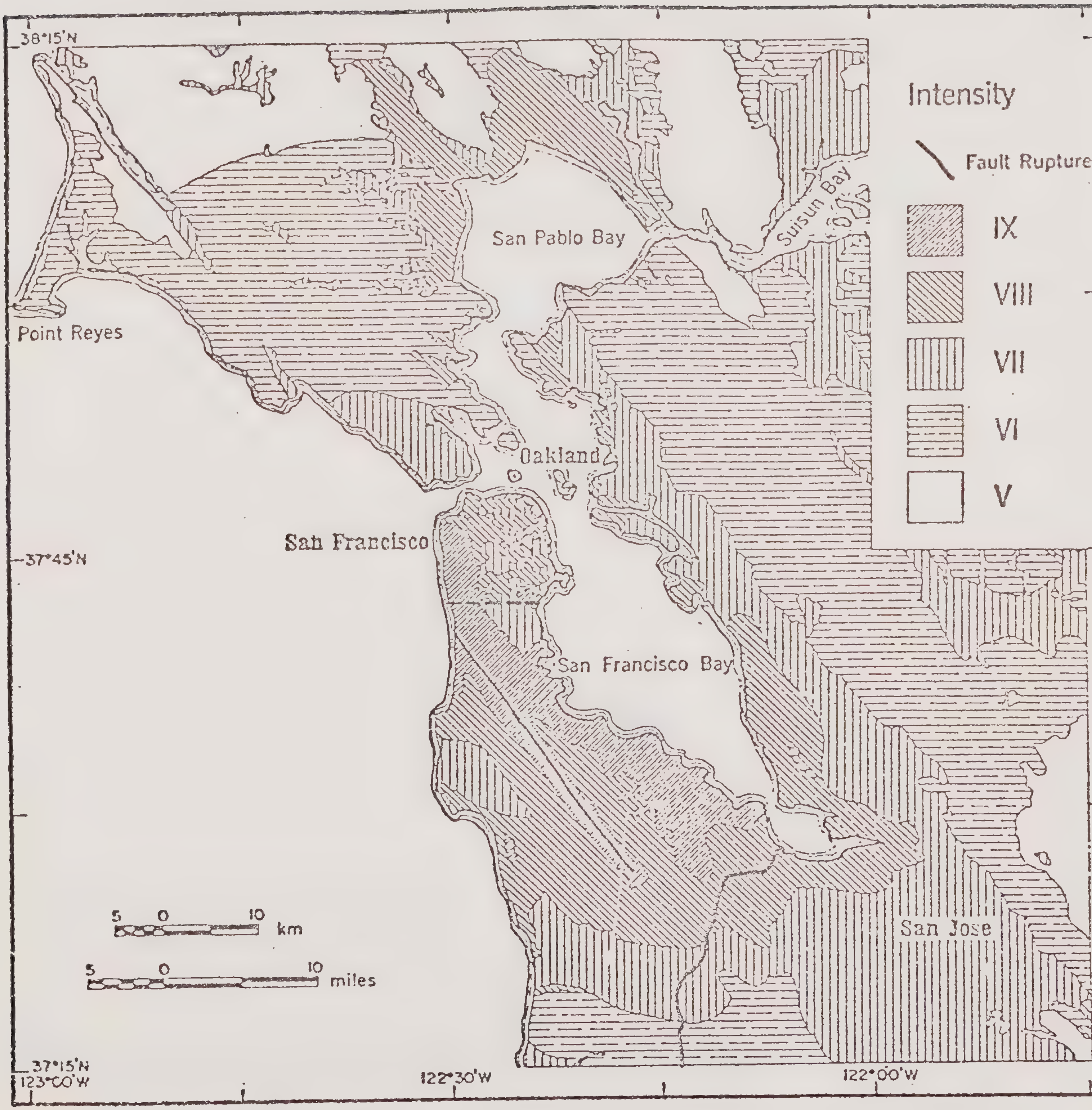
a. In the hillside areas in San Mateo County, permanent ground displacement may be found directly from faulting, but it is much more likely that such displacements will be associated landslides. With few exceptions, the hillside areas east of the San Andreas Fault have a relatively low landslide susceptibility. This statement must be tempered with actual site conditions including moisture content, and man-made changes such as cuts, fills, buildings, and water.

b. Unconsolidated and moderately consolidated deposits are found at the bottom of valleys and along both the bay and ocean planes.



Intensity distribution from a magnitude 8.3 earthquake on the San Andreas Fault.

FIGURE 10



Intensity distribution from a magnitude 7 earthquake on the San Andreas Fault.

FIGURE 11

Intensity distribution from a magnitude 6 earthquake on the San Andreas Fault.

FIGURE 12

When very soft deposits are subjected to the energy waves from an earthquake, their low degree of consolidation makes them act somewhat like a slab of gelatin on a plate and, depending on the specific conditions, there can be subsidence, ground cracking, lurching, and liquefaction.

3350. Active and Potentially Active Faults

3351. A fault is defined as an earth fracture or zone of fracture along which the rocks on one side have been displaced relative to those of the other. Geolgists have identified a large number of faults in San Mateo County. A summary of identified faults in San Mateo County is given on the United States Geologic Survey Map "Preliminary Geologic Map of San Mateo County, California," compiled by Earl E. Brabb and Earl H. Pampeyan, 1972. It is important to note that these faults are not classified with regard to becoming a potential source of damage in San Mateo County. It is difficult to locate faults in the well built-up portions of the County as a consequence of the changes in the ground surface associated with development. Modern techniques of fault location, using, for example, low angle photography, are difficult to employ in much of San Mateo County.

3352. The separation of identified faults into classifications with respect to their becoming possible sources of damage within a future time span is based first on the historical record of activity as evidenced by actual observed fault displacement. The San Andreas Fault is associated with the 1906 San Francisco Earthquake and the 1957 Daly City Earthquake. A fault can also be considered potentially active if there are strong indications of geologically recent activity. Such evidence is most often based on geologic observations of surface effects such as topography and stream offsets or by trenching the fault tract to observe those displacements that have occurred in the past but have development. It is often possible to approximately date the time these displacements occurred using Carbon Dating techniques. One definition is to consider all faults active for which there is evidence of displacement in the last ten to eleven thousand years.

3353. Potentially active faults can be subdivided into two groups, high and low potential. To be classed as high potential the offset from faulting must have taken place in the last ten to eleven thousand years (in Holocene deposits). Evidence of a groundwater barrier or anomaly in the same period, a record of earthquake epicenters from small earthquakes close to the fault, or strong surface evidence of recent faulting, qualify a fault as high potential. Low potential active faults have the same evidence except for recorded epicenters but in Pleistocene deposits (less than 2,300,000 years old).

3354. The active faults, probable active faults, and the associated fracture zones in San Mateo County have been identified by R. D. Brown, Jr., "Active Faults, Probable Active Faults, and Associated Fracture Zones, San Mateo County, California," U. S. Geological

Survey, Miscellaneous Field Studies Map MF-355. The dominant active fault in the County is the San Andreas Fault, which has been the source of earthquakes accompanied by surface faulting in 1838 and 1906. The San Gregorio Fault has been classed as active on the basis of epicentral locations, anomalous stream patterns, and apparent continuity with other seismically active zones. The Seal Cove Fault is considered to be a continuation of the San Gregorio Fault; it is believed that this fault joins the San Andreas Fault at a point north of the Golden Gate. The Serra Fault shows evidence of offset rocks as young as Pleistocene and small earthquake activity. Figure 13 delimits the area of major faults in San Mateo County.

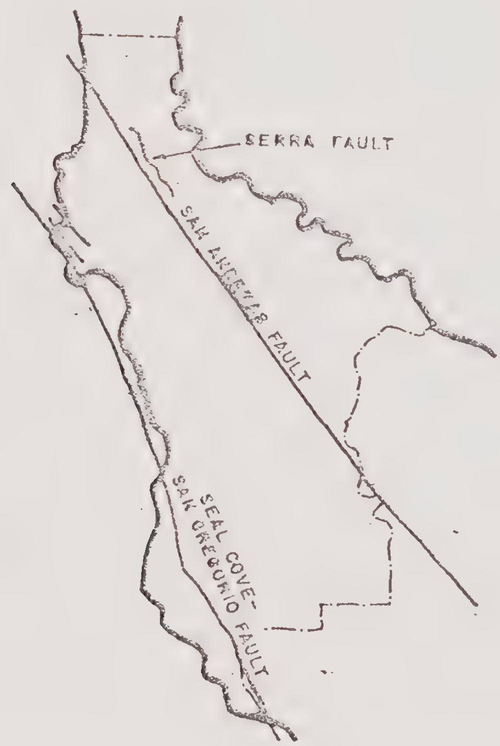


Figure 13

3355. To obtain a more complete picture of possible seismic events, it is necessary to consider active faults outside the County. For example, the Hayward, Concord and Calaveras Faults have the potential of producing strong ground motion in San Mateo County. Reference is made to the map by R. D. Brown, Jr. and W. H. K. Lee, "Active Faults and Preliminary Earthquake Epicenters (1969-70) in the Southern Part of the San Francisco Bay Region," U.S.G.S. Miscellaneous Field Studies Map MF-307, 1971. The discussion accompanying the map will be of interest to those desiring more information.

3360. Ground Shaking

3361. Ground shaking is the major cause of damage in any seismic event. It is, in fact, the common denominator in all seismic activities. Ground shaking is the result of a surface wave movement of the materials of the outer part of the earth's crust. It should be noted, however, that the degree of ground shaking is not entirely related to the proximity of the fault or epicenter but is also dependent on the composition of the underlying geologic conditions.

3362. Damage from ground shaking is caused by the transmission of frequency vibrations from the ground into the building. Every object has a response frequency, including buildings. When the building's response frequency is matched by the frequency vibrations from the building, vibration is amplified and the amount of damage created is related to the structural design, type of construction, height, and the intensity and duration of the ground motion.

a. Sources

As described earlier, various active and potentially active faults are present in and around San Mateo County that have caused measurable amounts of ground shaking in the past. The 1906 Earthquake and the 1957 Daly City Earthquake in recent past were due to the San Andreas Fault. Another active fault in the County is the San Gregorio Fault. The Seal Cove Fault and the Serra Fault are two other sources of ground shaking within the County. The Hayward and Calaveras Faults have, in the past, produced strong shaking in the County. The Concord Fault is another potential source of ground shaking. For further details, see "Active Faults and Preliminary Earthquake Epicenters (1969-70) in the Southern part of the San Francisco Bay Region," a map prepared by R. P. Brown, Jr. and W.H.K. Lee.

b. Recurrence

To get an insight into the recurrence of ground shaking due to past seismic events for San Mateo County, one must look at all the earthquakes of Richter Magnitude 5 and above for the San Francisco Bay Region. Table 1 gives this information for a time period of 1905 to 1969. The location of the epicenters is given in longitude and latitude. The County lies approximately between 37.1° North latitude to 37.73° North latitude and 122.1° East longitude to 122.5° East longitude. Table 2 indicates the frequency of occurrence for the San Francisco Bay Region. It can be seen from this Table that the majority of earthquakes are below Richter Magnitude 5. Only one earthquake above magnitude of 5 with an epicenter within the boundaries of the County has been recorded since 1900. That was the Daly City Earthquake of Richter Magnitude 5.3.

Tables 1 and 2 can be found on the following pages.

TABLE 1
EARTHQUAKES OF SAN FRANCISCO BAY REGION
(From 119°W to 125°W and From 35°N to 40°N)
(Richter Magnitude 5.0 and Above)

YEAR	DATE Mo. - Day	LOCATION		MAGNITUDE
1906	4 - 18	38.05°N	122.80°W	8.3
1911	7 - 01	37.25°N	121.75°W	6.6
1922	3 - 10	35.75°N	120.25°W	6.5
1926	10 - 22	36.57°N	122.18°W	6.1
1926	10 - 22	36.61°N	122.35°W	6.1
1932	2 - 26	36.00°N	121.00°W	5.0
1933	6 - 25	39.08°N	119.33°W	5.0
1934	6 - 05	35.80°N	120.33°W	5.0
1934	6 - 08	35.80°N	120.33°W	5.0
1934	6 - 08	35.80°N	120.33°W	6.0
1934	12 - 24	35.93°N	120.48°W	5.0
1936	6 - 03	40.00°N	125.00°W	5.8
1938	9 - 12	40.00°N	124.00°W	5.5
1938	9 - 27	36.30°N	120.90°W	5.0
1939	1 - 11	39.00°N	119.20°W	5.5
1939	6 - 24	36.40°N	121.00°W	5.5
1939	12 - 28	35.80°N	120.33°W	5.0
1940	7 - 08	37.45°N	119.00°W	5.0
1940	11 - 08	35.33°N	124.67°W	5.0
1940	12 - 20	40.00°N	124.00°W	5.5
1941	7 - 18	40.00°N	119.00°W	5.0
1942	12 - 03	39.70°N	119.30°W	5.5
1942	12 - 17	38.87°N	119.90°W	5.1
1943	3 - 30	39.43°N	120.40°W	5.3
1947	2 - 05	36.23°N	120.65°W	5.0
1948	12 - 29	39.55°N	120.08°W	6.0
1949	3 - 09	37.02°N	121.48°W	5.2
1951	7 - 29	36.58°N	121.18°W	5.0
1952	5 - 09	39.42°N	119.78°W	5.1
1952	7 - 21	35.00°N	119.02°W	7.7
1952	7 - 21	35.00°N	119.03°W	5.6
1952	11 - 22	35.73°N	121.20°W	6.0
1953	3 - 22	38.82°N	119.98°W	5.0
1953	9 - 26	39.53°N	119.98°W	5.3
1954	1 - 12	35.00°N	119.02°W	5.9
1954	4 - 25	36.93°N	121.68°W	5.3
1955	10 - 24	37.97°N	122.05°W	5.4
1955	11 - 02	36.00°N	120.92°W	5.2
1955	9 - 05	37.39°N	121.78°W	5.8
1956	11 - 16	35.95°N	120.47°W	5.0
1957	3 - 22	37.67°N	122.48°W	5.3
1959	3 - 02	36.98°N	121.60°W	5.3
1959	4 - 01	39.72°N	120.20°W	5.6
1960	1 - 20	36.78°N	121.43°W	5.0
1961	4 - 09	36.70°N	121.30°W	5.5
1961	4 - 09	36.68°N	121.30°W	5.6
1962	4 - 13	38.22°N	119.45°W	5.1
1962	6 - 06	39.07°N	123.32°W	5.2
1963	9 - 14	36.87°N	121.63°W	5.4
1964	11 - 16	37.06°N	121.69°W	5.0
1966	6 - 28	35.95°N	120.50°W	5.5
1966	6 - 28	35.97°N	120.50°W	5.1

Table 1 (Continued)

YEAR	DATE Mo. - Day	LOCATION		MAGNITUDE
1966	6 - 29	35.95°N	120.53°W	5.0
1966	9 - 12	39.43°N	120.15°W	5.3
1966	9 - 12	19.42°N	120.15°W	6.0
1967	12 - 18	37.00°N	121.78°W	5.3
1969	10 - 02	38.47°N	122.69°W	5.6
1969	10 - 02	38.46°N	122.69°W	5.7

TABLE 2

RECURRENCE OF EARTHQUAKES IN SAN MATEO COUNTY

MAGNITUDES	FREQUENCY OF EARTHQUAKES	CUMULATIVE FREQUENCY
3.0 - 3.19	323	1020
3.2 - 3.39	215	697
3.4 - 3.59	153	482
3.6 - 3.79	93	329
3.8 - 3.99	65	236
4.0 - 4.19	64	171
4.2 - 4.39	32	107
4.4 - 4.59	31	75
4.6 - 4.79	17	44
4.8 - 4.99	6	27
5.0 - 5.19	6	21
5.2 - 5.39	6	15
5.4 - 5.59	4	9
5.6 - 5.79	2	5
5.8 - 5.99	1	3
6.0 - 6.19	0	2
6.2 - 6.39	0	2
6.4 - 6.59	0	2
6.6 - 6.79	1	2
6.8 - 6.99	0	1
7.0 - 7.19	0	1
7.2 - 7.39	0	1
7.4 - 7.59	0	1
7.6 - 7.79	0	1
7.8 - 7.99	0	1
8.0 - 8.19	0	1
8.2 - 8.39	1	1

3363. Surface Rupture

a. The greater the magnitude of an earthquake, the stronger the possibility of service rupture. Ruptures normally happen at faults or other fault traces, but it is possible for ruptures to occur at other locations. The rupture begins at the focus and may extend upward to the surface. Such surface penetration is not predictable, albeit there is a good probability that it will happen in an area where previous ground rupture or cracking has occurred. Therefore, it is predictable that any structure located at the fault or surface rupture will experience serious damage. Consequently, building development should not be encouraged on or across known faults or fault traces.

3364. Ground Failure

a. Failure is another category of geotechnic hazards. Although normally associated with seismicity, such hazards can be caused by other factors. The principal forms of seismically induced ground failure are: landslides (with associated rockfalls, mudflows, and lateral spreading), liquefaction, and subsidence.

3365. Possibility of Ground Shaking on Unconsolidated Soils

a. It is a well known fact among geologists that the intensity and duration of shaking during an earthquake is many times greater on soft, water saturated ground than on solid rock. It is also well known that in an area of active faulting, the condition of the ground is a more important factor than the distance from the faults.

b. Over 50 years ago, G. K. Gilbert (1907, p. 12), in a report on the 1906 San Francisco Earthquake and fire, observed:

> "It has long been known that buildings and other structures on ground of certain kinds are more susceptible to earthquake injury than on ground of other kinds, and these differences were strikingly illustrated in San Francisco. The general fact appears to be that the amplitude of vibration and the acceleration are greater in loose, unconsolidated formations than in solid rock. The firmer and more elastic a rock formation, the less the intensity of the earthquake shocks in transmits to buildings standing on it; and there is a gradation in this quality from the firmest bedrock to the loosest gravel, sand, and mud. For strong shocks at least, the intensity is greater in loose formations saturated with water than those that are dry."

c. One of the earliest qualitative studies on the relation of the type of ground to the amplitude of ground motions was by H. F. Reid (1910). After the 1906 Earthquake, he estimated the resulting accelerations on various types of ground within San Francisco

and calculated the following Foundation Coefficient's:

Solid Rock	1.0
Sandstone	1.0 - 2.4
Sand	2.4 - 4.4
Man-Made Land	4.4 - 11.6
Marsh	12.0

In other words, Reid observed that ground motions were as much as 12 times greater on marsh than on solid rock.

d. Professor B. Gutenberg, seismologist from the California Institute of Technology, used the records of microseisms (small continuous disturbances of the ground) to determine the relative amplitudes of normal ground motion at stations on different types of ground and found amplitude factors, taking solid rock at 1; of sandstone, up to 3; dry sand about 3-1/2; and marshy land, 12 (1927). In a later study (1957) he used portable recording seismographs to estimate the effect of the ground on the amplitude and duration of shaking and concluded that "The amplitudes of earthquake waves and of the continuous unrest of the ground recorded at sites on on water saturated soft ground may be ten times more than those recorded in the laboratory" (located on solid crystalline rock). He emphasized the importance of selecting crystalline rock or at least dry ground for foundations of buildings to reduce potential earthquake damage.

e. In a study on the seismic characteristics of the ground, Kiyoshi Kani of the Earthquake Research Institute, University of Tokyo, concluded that (1957) "The larger damage rates on soft ground than on hard ground are due to the larger duration and amplitude of earthquake motion as well as to the unequal settling of foundations."

3366. Observations from major earthquakes along the margins of the Pacific Ocean Basin:

a. <u>San Francisco (1868)</u>: Magnitude near 7 on the Richter scale. Damage in San Francisco was confined chiefly to buildings on filled ground along the Bay (Tocher, D., 1959, p. 39-48).

b. <u>San Francisco (1906)</u>: Magnitude 8.3. "To some extent the earthquake caused damage to buildings and other structures in all parts of the City and County of San Francisco. The whole area was decidedly within the destructive zone. Still, over a large part of this area, for the larger part, the damage was slight, both in amount and character...there were relatively small districts, however, in which brick and frame buildings of ordinary construction were badly wrecked or quite destroyed. Pavements were fissured, buckled, and arched. Sewers and water mains were broken. In places, portions of streets were moved laterally several feet out of place. Well-ballasted streetcar tracks, equipped with 8, 10, or 11-inch rails, were arched and flexed or thrown into shallow wave forms. The whole land surface, sometimes for several blocks together, was deformed into shallow waves of irregular extension; length, and amplitude" (Lawson and others, 1908, p. 451). The destruction by Professor Lawson was confined chiefly to areas of man-made land and reclaimed marshland covered with fill.

c. Long Beach (1933): This earthquake had a magnitude of only 6.3 and hence is not considered a great earthquake, but among California earthquakes, the Long Beach Earthquake is second only to the 1906 San Francisco Earthquake in destructive effects. The greatest damage in the 1933 earthquake occurred in Long Beach and other coastal cities where unsuitable buildings had been constructed on man-made land or water saturated ground.

d. Kern County (Tehachapi) (1952): Schlocker and Radbruch (1955) noted that masonry and adobe structures built on rock or on a small thickness of natural or artificial fill overlying rock were undamaged or only slightly damaged. They determined that damage to structures built on fill increased with increasing depth of fill. Steinbrugge and Moran (1955) stated that steel structures of the Paloma Oil Refinery and the Maricopa Seed Farm, both located on former marsh and lake beds, were damaged more than unreinforced lime mortar brick buildings in Taft and Maricopa, on the Coast Range foothills.

e. Mexico City (1957): Most of the damage was to modern tall buildings built on an ancient lake bed composed largely of water saturated clay up to a 1000 feet thick (Duke and Leads, 1959, p. 179-192). Structures in Mexico City, 170 miles from the epicenter of the earthquake, built on water saturated alluvium suffered much heavier damage than structures of similar construction in Acapulco, 60 miles from the epicenter, built on granite.

f. Alaska (1964): Earthquake triggered landslides were responsible for most of the damage in Anchorage. A U. S. Geological Survey Report (1959) contained a warning about such landslides. In their report on the Alaskan Earthquake, Grantz, Plafker, and Kachadoorian (1964, p. 35) noted that "Structures built on bedrock were damaged less than those on unconsolidated deposits. For example, large concrete buildings at Whitter, built on bedrock, received less damage, although closer to the epicenter, than the concrete structures of Anchorage which were built on outwash gravel and clay."

g. Nigata, Japan (1964): Much of Nigata is built on land reclaimed from the sea, and after the earthquake a large area of this reclaimed land sank. Ocean water spread into a third of the city, and the water was up to three feet deep in places.

From these examples, it is a reasonable expectation that unconsolidated, water saturated soils are subject to ground shaking and associated ground failures from an earthquake occurrence. Therefore, a brief discussion of the nature of the so-called "young bay mud" is in order.

3367. Bay Mud

a. From studies conducted by the United States Geological Survey, it can be determined that Foster City is constructed on Bay Muds. Dames and Moore in their 1976 report to San Mateo County, entitled San Mateo County Seismic Safety/Safety Elements states that "The Bay Mud sediments in San Mateo County are composed almost exclusively of silty clay, but also contain occasional lenses of sand

and silt (principally in the area of San Bruno Shoals). Work done by consultants in the Redwood Shores area indicate little or no loss in strength during dynamic loading for silty clay samples of the Bay Muds. According to these same consultants, no significant amount of sand lenses within the Bay Muds were disclosed by the more than 250 borings made in the Redwood Shores property. The results of dynamic triaxial tests on samples of sand and gravel from the strata beneath the Bay Mud in the Redwood Shores area indicate that these lenses should remain relatively stable under seismic shaking" (Dames and Moore, 1976, p. 34).

b. Specifically for Foster City, the entire Foster City site was examined by the consulting firm of Dames and Moore in 1960 to determine its structural stability. The findings of the Dames and Moore 1960 report determined that the City was underlain by soft, compressible, organic silty clays, commonly called "Bay Mud." The depth of the mud encountered varied from 20 to 70 feet. The "Bay Mud" was underlain by firm clays and sands.

c. From evidence presented to this point in the report, several conclusions can be formulated regarding the structure of the strata in Foster City and its possible susceptibility to earthquake hazards. Unconsolidated, water saturated soils have a greater susceptibility to ground shaking than consolidated soil structures. Secondly, there is sufficient evidence to subtain the hypothesis that urban areas overlying unconsolidated materials are subject to damage from earthquakes and their associated hazards. Finally, Foster City lies on Bay Muds, which are by nature (to a depth of 70 feet) soft, unconsolidated materials that are subject to ground shaking and associated hazards. Furthermore, the nature of ground shaking will be sufficiently strong because the underlying Bay Muds and thick sequence of alluvial deposits tend to amplify seismic waves. The long period motion components will be amplified the most, but these waves are the least damaging to low structures, the type most prevalent in Foster City.

3368. Foster City Situation

a. The underlying natural soil is weak silty clay, approximately 40 feet thick in Unit 1 area and 25 to 100 feet thick over the Foster City area. It was reclaimed prior to 1900 by perimeter diking and drainage. The soil thus dried out, formed a crust several feet thick over the entire Foster City area. It has been sufficiently firm to operate heavy farm and construction equipment. The site conditions are quite uniform, except for the old sloughs, ditches around the perimeter, and levees. The sloughs and ditches have been filled with material excavated to form the interior lagoon, which has been placed and compacted to a density equal to or greater than that of the adjacent natural soil.

b. Hydraulic sand fill has been placed to a greater than four feet average thickness. It is fairly uniform, except as required for street and lot grading and drainage, and surcharge fill over ditches and sloughs (Nichols, C., June 10, 1963, letter to T. Jack Foster & Sons).

c. However, because of the subsurface condition of the site, it is expected that relatively large amplitude, low frequency ground motion will occur during earthquakes. Consequently, underlying soil conditions and future potential large earthquakes should be recognized by the builders, their structural engineers, architects, designers, etc., in the design of foundation and superstructure. Although low, (structures under 30 feet in height), lightweight, conventionally-framed structures located in Foster City do not appear to behave very differently under seismic loading than do similar structures elsewhere in the San Francisco Bay Area, tall structures founded on bay fill respond differently to seismic loading than do structures built on non-filled land.

d. Moreover, in respect to the impact of earthquakes in Foster City, soil engineers have stated that "It should be recognized that this area may be subjected to earthquakes with severe shaking and relatively large amplitudes or ground motion, although this site is comparable to many other sites in the vicinity of San Francisco Bay underlain by soft soils, these conditions should be recognized by the owners and provided for in the engineering design and construction of the structures and utilities. Although mass displacements of soil are not anticipated, local displacements of settlement may occur. Reinforcing and tying together of foundations, and other structural elements will help to minimize damage from strong earthquakes" (McKeon Construction Report to the State of California, Department of Real Estate, entitled Preliminary Subdivision Public Report, September 29, 1978).

e. The City of Foster City is constructed in an area which will undergo gradual subsidence over a long period of time. The majority of structures have been built in areas wehrethis subsidence is nearly uniform and will cause no problems. In certain areas, such as these areas once traversed by sloughs, the subsidence will not be uniform and may slightly tilt superimposed structures.

f. Since subsidence is viewed as a definite safety factor, the soil consultants have instituted a series of design criteria to insure a minor amount of differential settlement (U. S. Congressional Subhearings, May, 1969).

3369. Seismic Design

a. <u>One-Story Structure of Conventional Construction</u>: Residences framed with typical light wood framing and containing large areas of walls and partitions finished with lateral-force-resistant materials such as plywood or gypsum wallboard need no special seismic analysis.

b. <u>Two-Story Structures and One-Story Structures with Heavy Masonry Elements or Large Areas of Glass</u>: Although seismic data for areas such as Foster City indicates that light residential structures will not behave significantly different under seismic forces in bay fill areas than in many other bay area locations, the seismic resistance of structures described

in this paragraph deserves consideration regardless. However, it is recommended that residential structures which are unusually high or heavy and lack support offered by long lengths of stiff walls and partitions be analyzed for seismic resistance in accordance with Chapter 23 of the 1964 Uniform Building Code and strengthening elements be provided where necessary (Hearings before a Subcommittee of the Committee on Government Operations, House of Representatives, May 7 and 8, 1968, pp. 96-101).

4000. *LEVEE SYSTEM SEISMIC SAFETY AND MAINTENANCE PROGRAM*

4100. In the mid to late 1960's, concern was voiced by those who were critical of the construction of the City of Foster City on the Bay Muds, and the resulting construction of the levee system. The specific issue in respect to the levee system, concerned their possible damage from a seismic event. Also, concern was raised about the maintenance program of the levee system, which had been instituted by the City to substain the structural integrity of the levees. The criticism resulted in May of 1969, with Congressional Subcommittee Hearings being held in Washington, D. C., with the express purpose of examining federal involvement in hazardous geological areas in the State of California. A major portion of these hearings were focused on the Foster City situation. In August of 1969, Congressman Pete McCloskey conducted hearings in San Mateo to clarify what had occurred at the May, 1969 Congressional Hearings.

4101. Later in this report, the current maintenance program will be examined and its relationship to the Federal Housing Administration standards tested. It should be noted in this report that the Federal Housing Administration and Veterans Administration mortgage insurance guarantees at Foster City had been briefly halted in August of 1969. Such participation had been halted in August of that year when the House Government Operations Committee, of which McCloskey was a member, recommended that further studies of dike safety be made at both Foster City and Redwood Shores and that there be an additional study of earthquake hazards at Redwood Shores.

4200. In a letter to Special Studies Subcommittee Chairman John S. Monagan, dated June 25, 1970, Federal Housing Administration Commissioner Eugene Gulledge stated that even if there was a stability deficiency in the Foster City levees, "...which remains debateable, only minor flooding would occur from levee failure." Commissioner Gulledge took cognizance of the fact that more than 2,300 families living in Foster City are aware of the importance of the levees and control the maintenance through the Estero Municipal Improvement District.

4201. Upon the Government Operations Committee's acquiesence in his decision, Commissioner Gulledge implemented it with instructions to the San Francisco Office of Federal Housing Administration effective Monday, July 13, 1970, as well as to the Veterans Administration. The Federal Housing Administration as of July 13, 1970, began to accept applications for subdivision approval on the three remaining neighborhoods of Foster City not approved prior to the August, 1969 moratorium (McCloskey News Release, July, 1970).

4202. Moreover, in a letter, dated July 16, 1970, to T. Jack Foster from Roy H. Pinkerton of the Department of Housing and Urban Development, the importance of maintenance of the levees was stressed: "Although we are satisfied with the present condition of the levees, we are still concerned that they receive continous regular maintenance and prompt emergency attention as required. We hope that the Estero District and others concerned will dilligently purse this matter in order that legal problems will be promptly resolved and the District will be in a position to reaffirm its responsibility for levee maintenance." (Pinkerton letter, July 16, 1970).

4203. The following is from an October 1961 Geological Survey summary that was conducted for the Federal Housing Administration. The relevant comments follow:

a. "Many types of failure caused by earthquakes that could damage dikes about the site of Foster City have been considered. With the information available, however, it is difficult to draw conclusions with respect to the kind and extent of damage the dikes might incur during a strong earthquake shock. Following are important points to be considered in evaluating earthquake stability of the dikes.

1. Mud dikes, including the ones around Brewer Island, were in existence at the time of the 1906 California earthquake. The writers found no published information about damage to any of the dikes. In fact, the only statement about how the dikes fared during the earthquake is a brief one in a letter written July 18, 1906, to C. E. Whitney and Co., San Francisco. Most of the letter deals with other matters about salt works near San Mateo, but near its end is the statement that the earthquake caused about $1,000 worth of damage to machinery and levees. No mention is made of the kind and extent of damage to the levees.

2. The meager information available suggests that the dikes around Brewer Island survived the 1906 earthquake. In considering what this may mean about the stability of dikes during a future strong shock, it must be kept in mind that at the time of the 1906 earthquake the dikes along the bay sides of the island were 200 to 400 feet back from shore whereas today the bay side of the dikes is the shoreline. Furthermore, plans for development of the site of Foster City calls for placing fill to the top of the dikes. If this should materially reduce the factor of safety compared to what it was for the dikes in 1906, there will be increased possibility of failure by landsliding during a future strong shock." (Report to the Committee on Government Operations House of Representatives, 1967, p. 19-20).

4204. In July, 1961, at about the same time that the Federal Housing Administration (FHA) retained the Geological Survey as a consultant, the FHA central office also requested the Corps of Engineers to review and evaluate various aspects of the dikes, such as stability of foundation, suitability of materials, minimum safe height, slope protection, and other pertinent factors affecting stability and suitability of dikes. The Corps of Engineers also was to determine whether the data obtained by the sponsor's consultants was adequate.

4205. The Corps of Engineers report was issued to the FHA under a covering letter dated June 21, 1962. The conclusions presented had been previously discussed informally by the Corps with FHA representatives on May 31, 1962. Although the report contains no reference to earthquakes, Corps officials stated that the potential effects of earthquakes were considered by the Corps in arriving at its determination.

4206. The report states that the elevation of the levee system around the perimeter of the island would have to be equal to or higher than certain specified heights to be acceptable under the Corps of Engineers criteria and practices and to insure the integrity of the project. Also, criteria for slope protection of the east and north levee was given with the statement that any lesser degree of slope protection would require an extensive maintenance program with stockpiles of stones for emergency repairs during and immediately after storms.

4207. The definition of extensive maintenance as used by the Corps follows:

a. "The slope protection construction criteria ... are based upon design criteria of the Chief of Engineers, developed from experience over many years and from many locations, and found to give results which will provide essentially maintenance-free protection when subjected to storms up to and including the design storm. Being, thus, predicated upon a minimum of maintenance, the answer is closely related to the second question also.

b. As the design is predicated upon stability under attack by the design storm, it follows that slope protection of lighter construction would be damaged by the design storm. Such damage would be expected to extend throughout the length of such lighter protection which is under attack.

c. While extensive maintenance can be rather well defined, as above, the degree of the damage, which would occur throughout the damaged portion, is less definitely defined. The severity of damage experienced in any single storm would depend upon the degree to which the slope protection departs from criteria-design construction; it would depend also upon the severity and duration of the actual storm relative to the design storm. These

are factors for consideration if construction less than the criteria design was to be comtemplated, along with such other factors as availability, capability, and sufficiency of emergency maintenance possibilities. If the maintenance provisions are less than adequate, then the additional factor of 'calculated risk' would enter the consideration. These programs relate to policy and other program aspects appropriate to the responsible agency."

4300. Inasmuch as the Congressional Subcommittee Hearing was conducted in May of 1969 to examine the Foster City situation, Congressman Paul McCloskey conducted hearings in San Mateo County in August of 1969 to reexamine the findings of the Congressional Subcommittee. The comments made by McCloskey and others place the issue of seismic safety and the levee system in proper perspective. The discussions involved whether or not the FHA and Corps of Engineers had to agree on the dike stability factor of 1.0:1 rather than the 1.5:1 safety factor. The statement made by McCloskey is in Appendix A.

4301. Later in the hearing, Congressman McCloskey denoted the real reason for the Congressional Subcommittee Hearings dealing with seismic safety in California. McCloskey said in part that it was an inquiry into whether the FHA had adequate procedures in areas of seismic risk and whether they had followed these procedures or not. The statement made by McCloskey is in Appendix B.

4302. The series of statements made at the McCloskey Hearing, established the significance of the 1:5 and 1:1 ratios that were so crucial to the structural integrity of the levee system. Essentially, the 1.5:1 ratio meant that all known possibilities that might occur, have been considered in the design of the levee system. If the levee system is designed to withstand these possibilities, then a design of 1:1 has been established. If the strength of the levee is increased by 50 percent, the ratio is increased to 1.5:1. According to the statements from the hearing, it was concluded that it was virtually impossible to achieve a 1.5:1 dike stability ratio against lateral movement. These statements can be found in Appendix C.

4303. In a letter from Kenneth E. McIntyre, dated May 18, 1969, then a Lieutenant Colonel, United States Army Corps of Engineers, and Assistant Director of Civil Works for the Pacific Division to Congressman John S. Monagan, attention was directed to the 1:1 and 1:5 ratios. McIntyre gave a more technical discussion of these ratios. His analysis was essentially what had been said in the McCloskey Hearings. Also, McIntyre discussed the issue of tsunamis and their impact in San Francisco Bay and the Foster City area. He concluded that the configuration of San Francisco Bay and the Golden Gate are not conductive to generation of high water levels in the Bay from tsunamis developing in the Pacific Ocean. The full text of the McIntyre letter appears in Appendix D.

4304. One of the major conditions for reinstatement of the Federal Housing Administration and the Veterans Administration Mortgage insurance was a specific levee maintenance program. It will be seen that the program instituted by the City of Foster City in the early 1970's is in full compliance with the 1962 Federal Housing Administration guidelines.

4305. The Estero Municipal Improvement District in January of 1973 acquired maintenance easements for levees formerly held in private ownership and thus undertook increased responsibility for the integrity of the exterior levee system.

4306. Accordingly, the Board of Directors authorized the preparation of an updated definitive maintenance program for the entire levee protective system for Foster City.

4307. In September, 1962, the Federal Housing Administration summarized criteria which was applicable to the development of Foster City. These requirements are reproduced in Appendix E.

4308. After reviewing correspondence subsequent to the Federal Housing Administration, letter dated September, 1962, and the inspection of the levee system as it existed in 1973, it was concluded that the original 1962 requirements are essentially valid currently except for certain modifications and interpretations discussed below (refer to Figures 14, 15, 16 and 17 for clarification of levee names and locations).

4400. North Levee

4401. Crest elevations are to be maintained at 109.8' (9.8 M.S.L. Datum). Since the Federal Housing Administration requirements were established, filling has taken place on lands north of Third Avenue (123-acre site). This area itself is protected by a secondary levee with rock protection (North Shore Outboard Levee) which effectively protects Third Avenue against wave action. It was recommended that rip rap not be required for portions of levee which are behind this filled ground and are therefore not subject to direct wave action from the Bay.

4402. Further, after the Federal Housing Administration requirements were established, the Seal Slough (Marina Lagoon) Inboard Levee was subsequently constructed to follow the Foster City boundary adjacent to the Mariner's Island development. This levee intersects North Levee at the intersection of Third Avenue and Mariner's Island Boulevard, and effectively closes the circumferential levee system for Foster City.

4403. Because of this closure of the circumferential levee and the additional protection afforded by the North Shore Outboard Levee, it was concluded that no further maintenance is justified by the City on the Third Avenue levee from Mariner's Island Boulevard westerly to Seal Slough within the City of San Mateo.

4500. North Shore Outboard Levee

4501. This levee was not included in the criteria reviewed by the Federal Housing Administration in September 1962, presumably because at that time planning for the north shore reclamation was not complete. This levee is protected by heavy rip rap which appears to have been placed as material became available and is, therefore, not uniformly graded nor efficiently constructed for maximum erosion protection. Nevertheless, the levee provides valuable protection for the north shore reclamation area fill and in turn prevents wave action from reaching the portion of the Third Avenue levee lying south of the North Shore lands. The rip rap has collapsed in one or two places and erosion of the patrol road is in process. It is apparent that erosion will be accelerated during the winter storm period which in turn may result in a wash out of the very fine-grained fill material placed behind the levee.

4502. It was recommended in 1973 that the District make periodic inspections and require the owener to make immediate repairs to prevent washouts and to maintain the general integrity of the levee.

4600. East Levee (Sections 2-A and 2-B)

4610. Section 2-A

4611. The crest elevation is to be maintained at a minimum elevation of 109.0 feet. Heavy rip rap protection exists on the outboard slope. The crest width is 20 feet or more as this levee has served in the past as an access road for the initial District reclamation program. It was recommended in 1973 that a minimum width of 20 feet be retained to facilitate access of heavy equipment for rip rap maintenance and stability against wave action.

4620. Section 2-B

4621. This levee is protected against wave action by a sand beach shoreline which eliminates the requirement for rip rap slope protection. Otherwise the maintenance requirements are the same as 2-A above.

4700. Belmont Levee (Sections 3-A, 3-B and 3-C)

4710. Section 3-A

4711. The land outboard of this levee is outside of the District but within the Foster City limits. The outboard lands are owned either by the State of California or Westbay Associates and are protected from inundation by an outer dike which is not part of the District Levee System.

4712. The District Levee is to be maintained at elevation 108.1' (Federal Housing Administration requirement) with a minimum 12-foot crest width.

4720. Section 3-B

4721. Section 3-B fronts on a tidal marsh area bordering Belmont Slough. This section is for an interim improvement condition during the land fill stage of the adjacent areas. A minimum crest elevation of 108.5' is recommended to allow for some nominal settlement following the placement of adjacent areal fill. It was also recommended that continued maintenance at elevation 108.5' rather than the Federal Housing Administration criteria of 108.1' to allow for any minor surge or backwater effect in Belmont Slough. The minimum crest width is 4 feet with a 12-foot patrol road located inboard of the crest.

4730. Section 3-C (Outboard)

4731. Section 3-C is located in former tideland areas, now diked off from the Bay. It was constructed as a retaining dike flanking a temporary across channel excavated by a floating dredge to reach Marina Lagoon from the tidal waters of Belmont Slough. The dike now functions as a secondary outboard levee protecting Neighborhood 8. The crest elevation is to be maintained at elevation 106.4' with a crest width of 4 feet minimum, pending resolution of final planning for the former tideland areas.

4740. Section 3-C (Inboard)

4741. This section is presently oversized and forms part of a sand stockpile. It was recommended that the crest elevation be regraded to elevation 108.5 with a crest width of 12 feet and a rear slope of 1:3.

4742. The levee is located adjacent to former tideland areas now diked off from the Bay. The original Federal Housing Administration criteria required a minimum crest elevation of 108.1.

4800. Marina Lagoon Seal Slough (Sections 4-A, 4-B, 4-C and 4-D)

4801. Crest elevations were originally specified to be maintained at elevation 106.5 (6.5 M.S.L. Datum). This requirement was later modified slightly to elevation 106.4. The function of this levee is to protect against flooding from Marina Lagoon, which is designed to a lesser degree of protection (20- to 30-year storm) than Foster City (100-year storm).

4802. The levee crest height of elevation 106.4 closely corresponds to the estimated highest tide for still water conditions. This Seal Slough levee therefore appears to afford protection to Foster City against complete inundation of Marina Lagoon by Bay waters under extreme tidal conditions, caused by complete failure of the City of San Mateo pump house structure and dam.

4810. Section 4-A

4811. Section 4-A forms the frontage of Neighborhood 8 on Marina Lagoon. The required crest elevation is 106.4 minimum. Minimum crest width is three feet.

4820. Section 4-B

4821. Section 4-B forms the frontage of Neighborhood 9 on Marina Lagoon. In 1973, it was being reconstructed as part of a townhouse development and when completed and if maintained, will provide the protection intended.

4830. Section 4-C

4831. Section 4-C shows evidence of appreciable bank erosion. As an interim protective measure, it was recommended that a new levee be constructed with a crest elevation of 106.4.

4840. Section 4-D

4841. Section 4-D functions as an inboard dike located along the boundary line between Foster City and Mariner's Island. The existing dike varies greatly in height and section.

4900. Updating of Levee Standards and Inspection and Maintenance Procedures

4901. The standards should be reviewed from time to time and revised to conform to any change of levee use such as recreation, walks, trails or levee parks.

4902. Alternate sections may be considered which are less formal in configuration and lend themselves to varying landscaping treatment while providing an equivalent degree of protection to the developed areas.

4903. Visual inspection should be made at least every six months and after every major storm. The north levee is exposed to significant wave action and should be checked for failure or undermining of the rip rap slope protection. Elsewhere, inspection for uniformity of the levee crest height and width should suffice. An instrument survey should be ordered immediately and levels taken if there is doubt regarding elevations.

4904. Every five years or less an instrument survey should be made to check the crest elevations against the required Federal Housing Administration criteria. Results should be plotted on a master print and kept on file so that any particular trouble spots show up by comparison.

4905. Unless urgent storm repair is required, routine maintenance is preferably scheduled in the summer months. Truckloads of oversize rock or broken concrete from other nearby construction projects may be suitable for periodic reinforcing of rip rap, particularly the North Shore levee. Levee build-up requiring import material should preferably be scheduled to coincide with a District fill project. Fill material used for topping out levees should contain sufficient cohesive fines to bond the fill material and prevent wind erosion of the narrow crested section.

4906. Minor build-up of the crest may be accomplished by local or drifting of material from highs to lows. On wide crested levees a cross slope may be introduced or slightly accentuated to provide a build-up of the crest line (Daniel, Mann, Johnson and Mendenhall, January, 1973, p. 1-12).

FIGURE 14

ESTERO MUNICIPAL IMPROVEMENT DISTRICT

EXTERIOR LEVEE SYSTEM


SAN MATEO BRDG.
SAN FRANCISCO BAY
EAST LEVEE
2-A
2-B
Third Avenue
19th. Ave. Freeway
Foster City Boulevard
Blvd.
Shell Blvd.
East Hillsdale Blvd.
Edgewater Blvd.
Beach Park Boulevard
MARINA LAGOON
BELMONT SLOUGH
EAST LEVEE (2-A & 2-B)
DISTRICT BOUNDARY

FIGURE 15

ESTERO MUNICIPAL IMPROVEMENT DISTRICT

FIGURE 16

SAN MATEO BRDG.
SAN FRANCISCO BAY
N
Third Avenue
19th Ave. Freeway
Foster City Boulevard
Hillsdale Blvd.
East
Shell Blvd
Edgewater Blvd.
Beach
Park Boulevard
BELMONT SLOUGH
MARINA LAGOON
④ MARINA LAGOON LEVEE
INBOARD LEVEE
4-D
4-C
4-B
4-A
MARINA LAGOON LEVEE (4A, 4B, 4C & 4D)
DISTRICT BOUNDARY

FIGURE 17

5000. *SEISMIC SAFETY OF BRIDGES IN FOSTER CITY*

5010. Although many countries throughout the world have experienced seismic damage to their bridges, very few bridges in the mainland United States have subtained serious damage prior to 1971. The total damage to California's bridges prior to that time was approximately $100,000 in today's money (1978). The little damage that did occur was limited to minor spalling and cracking of concrete, damaged bearings and ground pads, and slightly shifting of spans.

5020. Two major freeway-to-freeway interchanges were under construction within the narrow region close to and possibly within the fault zone of the February 1971 San Fernando Earthquake. That event had a magnitude of 6.6 on the Richter scale. That 12 seconds worth of shaking did about $6.5 million worth of damage to the freeway structure.

5030. The 1971 earthquake pointed out a number of deficiencies in bridge design specifications and detailing practices. The greatest deficiency discovered was that segments of superstructures were not properly tied together. The second most serious deficiency discovered was that many reinforced concrete columns have insufficient ties and spirals, and splices were often made with inadequate laps and in concrete with too little confinement.

5040. Column deficiencies greatly increase the structural weakness of a bridge when segments of the superstructure are not tied together.

5050. It is not practical to design bridges that will economically serve normal transportation needs but not be damaged to some extent if subjected to severe seismic shaking. The aim is to make structures seismically resistant to the extent that they may sustain damage but not collapse completely. It is also desirable that they be capable of carrying at least a minimum amount of emergency traffic even though they may be damaged. Although retrofitting existing structures will increase their seismic resistance considerably, a designer is limited by the existing facilities and by economics. Portions of some existing structures have to be strengthened to accommodate the anchorage forces that restrainers require. In some cases, restrainers that would develop forces required to hold segments of a bridge together would pull the ends out of the spans or pull over the columns. When hinges are not restrained, segments of a bridge can act independently and forces in the columns can be significantly greater than if hinge movements are limited. Thus, retrofitting hinges with restrainers can significantly reduce the probability of column failures.

5060. In respect to the Foster City situation, a major issue facing the City is the problem of access and circulation. This problem has a commmon denominator -- the dependence of the City on bridges and culverts. Ingress and egress to Foster City is gained at four points: Third Avenue, Hillsdale Boulevard and east and west on Highway 92 (San Mateo-Hayward Bridge). All of these approaches involve, at some point, crossing water. In the event of a major earthquake, the City bridges may be effectively damaged and/or destroyed. There is also a great potential for interior disruption within the City, due to a number of bridges. This problem

is mitigated to some extent by the fact that some of the water bodies are quite shallow and can be waded across. Many of the residents of Foster City also have boats.

5070. However, it should be pointed out that the State of California (Caltrans) examined the seismic safety factor for the bridges in Foster City in 1976 and found them to meet State seismic safety standards (from discussion with Richard K. Hopper, Public Works Director, City of Foster City, March, 1979).

6000. *FINDINGS, POLICIES, AND RECOMMENDATIONS*

6100. Seismicity

6110. General Seismicity

6111. Findings:

a. Earthquakes and faulting are a response of rocks to stresses which are set up within them. During the fault movements, strain energy that has accumulated in the earth's crust is converted into earthquake producing elastic wave energy which radiates from the moving fault plane. The resulting ground motion is responsible for the majority of earthquake damage.

b. Worldwide, the U. S. Coastal and Geodetic Survey reports approximately 5,000 earthquakes per year. Annually, California can expect to experience more than 500 earthquakes which will be strong enough to be recorded by general purpose seismographs. It should be noted that the monitoring of earthquakes in California is much better than the world generally.

c. The great majority of earthquakes are not dangerous to life or property either because they occur in sparcely populated areas or because they are small earthquakes which release relatively small amounts of energy. However, where urban areas are located in regions of high seismicity, damaging earthquakes are expectable if not completely predictable events. For example, the San Francisco Bay Region has been impacted by more than ten severe earthquakes during historic time.

d. Substantial earthquakes are typically followed by aftershocks. Some aftershocks can be highly damaging, particularly when centered in densely populated areas or in areas where manmade structures or the ground has been weakened by the main earthquake.

Mankind has the capability, through wise land use planning, taking into account the materials and forces of the earth itself, to mitigate the destructiveness of even the most severe earthquakes.

6112. Policies:

a. In an area of high seismicity, planning, development, and building should incorporate scientific and engineering knowledge of earthquake causes and the response of ground and structures to earthquake forces.

6113. Recommendations:

a. All levels of government, including the City of Foster City, responsible for guiding and regulating development and building in seismic areas should adopt plans, policies and procedures, and enact legislation, to ensure the application of scientific and engineering knowledge to the protection of lives and property.

6120. Local Seismic Activity (Foster City and Surrounding Area)

6121. Findings:

a. Between 1906 and 1978, San Mateo County has experienced only three major earthquakes.

b. The County has experienced 58 earthquakes of Richter Magnitude 5.0 and above in a time frame of 1906-1969.

6122. Policies:

a. Public policy in San Mateo County and including Foster City must recognize that the County is in an area of prevailing high seismic activity in which earthquakes of all levels of magnitude occur.

6123. Recommendations:

a. San Mateo County and Foster City should actively seek to obtain county-wide coverage of the monitoring of seismic activity.

6200. Earthquakes

6210. Causes of Earthquakes

6211. Findings:

a. The "Plate Tectonic Theory," which holds that the earth's crust is composed of lithospheric "plates" that are systematically shifting and changing forms over a semi-plastic under surface, for the first time satisfactorily accounts for earthquakes and their distribution.

b. No place on earth is totally safe from earthquakes, but most cluster in narrow, continuous belts of high seismic activity that coincide with the boundaries of lithospheric plates.

c. According to the Plate Tectonic Theory, the San Andreas Fault is a major transform fault which forms the boundary between two major lithospheric plates. That portion of California which lies west of the San Andreas is part of the Pacific Plate; the area east of the San Andreas is part of the Americas Plate.

d. The actively spreading East Pacific Rise causes stress to accumulate in rocks along the San Andreas Fault. When the stored energy equals the resistance of these rocks to shearing, fault movement occurs on the San Andreas system and California has another earthquake.

6212. Policies:

a. In an area susceptible to high seismic activity, public policy should recognize that a severe earthquake hazard exists and reflect this knowledge in their programs.

6213. Recommendations:

a. All levels of government including the City of Foster City functioning in areas susceptible to high seismic activity should direct their agencies to give appropriate attention to seismic safety in the creation and execution of their programs, and cooperate with one another to ensure the effectiveness of their efforts.

6220. <u>Earthquake Measurement</u>

6221. Findings:

a. Two kinds of systems are universally used to describe earthquakes: the objective mathematically precise "magnitude" scale (Richter Scale) necessary for instrumental measurement and scientific work; and the more subjective "intensity" scale (Modified Mercalli Scale) that describes locally perceived effects.

b. California has an extensive seismic monitoring system.

6222. Policies:

a. In seismically active areas, it should be public policy to obtain an operational system of seismic recording instruments and related information transmittal system.

6230. <u>Earthquake Geologic Effects</u>

6231. Findings:

a. The major geologic effects of earthquakes are: fault displacement, ground shaking, ground failure, and flooding.

6232. Policies:

a. Public policy regarding seismic safety should consider each of the geologic hazards affecting the area.

6233. Recommendations:

a. Governments including the City of Foster City in seismically active areas should individually and cooperatively work to identify and evaluate their geologic hazards, and direct their agencies to consider each in their programs.

6240. <u>Earthquake Probability</u>

6241. Findings:

a. Because of the complexities of the earthquake phenomenon, the short documented history of Bay Area seismic activity, and the

inadequacies of current technology, the prediction of the magnitude, time of occurrence, or location of earthquakes is presently unreliable.

6242. Policies:

a. Public policy in Foster City regarding planning, building and development should be based on the assumption of occurrence of earthquakes of the magnitudes found in Tables 1 and 2 in the Ground Shaking Section.

6243. Recommendations:

a. Not only should public policy in Foster City accept the premise of earthquake occurrence and associated damage occurring, but it should also require that structures that must withstand earthquakes to protect life or provide significant service be designed to withstand anticipated static and dynamic loads.

6300. Faults

6310. Fault Displacement

6311. Findings:

a. A fault is a fracture in the earth's crust along which the two sides have moved relative to each other. It should be recognized that all active and potentially active faults have a high probability of future movement.

b. Evidence of active faulting may include: (1) historic earthquake accompanied by surface faulting; (2) tectonic creep; (3) offset of deposits of known or inferred Holocene age (less than approximately 11,000 years); and (4) fault trace defined by youthful fault related topographic features.

c. Evidence for a "potentially" active fault may include: (1) major historic earthquake in immediate vicinity of a fault; (2) alignment of epicenters along a fault trace; (3) offset of deposits of known or inferred Quaternary age (less than approximately 2 million years); and (4) fault trace defined by eroded, subdued or discontinuous fault related topography; and 5) trace which is mechanically related to an active fault.

6312. Policies:

a. All faults, active or otherwise can adversely affect structures built over or near them and need to be taken into account in the design of buildings and developments.

b. Structures for human occupancy and structures for public safety should not be built over the trace of an active or potentially active fault. (It should be noted that Foster City does not have any active or potentially active faults.)

6313. Recommendations:

a. Governments in seismically active areas including the City of Foster City should work individually and cooperatively to locate faults, classify them, and any new fault zones.

6320. Local Faults

6321. Findings:

a. Earthquake faults are inherent features of San Mateo County's geological structure and inherent in the geological processes that produced it.

b. Earthquake faults are numerous in the County, but are not "everywhere." There are "no" active or potentially active faults to be found in the City of Foster City.

c. An impressive body of information of faults exists for San Mateo County. The principle sources of data include the mapping of the United States Geological Survey, field studies performed by registered geologists, studies conducted by private consultant firms, and studies conducted by universities and research institutions. This information is suitable to accomplish many policy planning and project review functions, and generally to guide land planning.

6322. Policies:

a. Since there are no active or potentially active faults within the political boundaries of Foster City, there can be no precise recommendations or policies made regarding construction of structures on or near faults.

6400. Ground Shaking and Ground Failure

6410. Findings:

a. Energy released by an earthquake is transformed into ground waves which radiate outward from their location or origin in a fault.

b. Ground shaking from surface waves is generally the most destructive earthquake effect. Severe ground shaking may occur tens of miles distant from a strong earthquake.

c. Ground shaking during an earthquake may be more severe on poor ground located farther away from an earthquake fault than on solid ground in close proximity to the fault.

d. It has long been recognized that the performance of a structure during an earthquake is closely related to the nature of the ground on which it rests.

e. Ground failure occurs when stresses in the ground exceed the resistance of earth materials to deformation or rupture. This instability can be triggered by earthquake shaking, which instantaneously places high stresses on earth materials.

f. The manifestations of ground failure are complex and highly variable; they include numerous varieties of landslides, sloughing, liquefaction, ground cracking, lurching, subsidence and differential settlement. The type of ground failure that develops in a particular area depends on topographic, geologic, hydraulic and engineering characteristics of the ground.

g. The ability of a structure to resist earthquakes is greatly influenced by the ground conditions at the site. Historically, structures which have been built on swampy, continually wet, unconsolidated sediments, non-engineered fill have sustained severe levels of damage during earthquakes.

h. Foster City, because of the subsurface condition found on the site, is expected to experience relatively large amplitude, low frequency ground motion during an earthquake.

6420. Policies:

a. In seismically active areas, ground conditions should be a primary determinant of land use and of the design of developments.

b. In seismically active areas, structures for human occupancy should be designed to survive anticipated earthquake forces without endangering life.

c. Structures for human occupancy, or those whose loss would substantially affect the public safety or the provision of needed services, should not be erected in areas where there is a high risk of destruction in the event of anticipated earthquake conditions.

d. In areas prone to severe levels of damage from ground shaking, the risks to life and investments are sufficently high to warrant geologic, seismic and soils studies as a precondition for authorizing public or private construction.

6430. Recommendations:

a. Governments, including the City of Foster City, in seismically active areas should work individually and cooperatively to identify and evaluate ground conditions, relative to land use and building conditions, in their jurisdiction.

b. Governments, including the City of Foster City, in seismically active areas should adopt plans, policies and procedures, and enact legislation to implement the above policies.

6500. Flooding and Seismicity

6510. Findings:

a. Historic records have repeatedly shown that fault displacement and accompanying ground shaking are capable of causing severe flooding. Floods can be triggered by dam failure, tsunamis, and seiches.

b. Because many dams create terminal storage and serve as distribution reservoirs for municipal water systems, they must necessarily be sited on high ground adjacent to population centers. Thus, the rapid failure or an important dam would lead to catastrophic results to the downstream population.

c. Although it is recognized that the possibility of tsunami occurrence cannot be eliminated if overtopping does occur, flooding may be limited to the area near the dikes, or between the dikes and the interior lagoons.

d. There are two dams that are a potential hazard to the City of Foster City, the Crystal Springs and San Andreas Dams. If, however, there is a dam failure, there can be at the moment no adequate determination of the level of the flood waters that might strike Foster City. It does seem reasonable to assume that flood waters travelling the distance from Crystal Springs and San Andreas Dams and the time element involved (2 hours, 30 minutes) would result in the reduced height of the flood waters. It can be further assumed that if there is flooding, it would be of a very minor nature.

6520. Policies:

a. Dam and levee failure, as well as potential inundation from tsunamis and seiches, should be a significant consideration in land use planning.

b. Dams (and their empoundments) and levees should be designed to withstand the forces of anticipated (design) earthquakes at their location.

c. Dams (and their empoundments) and levees should be regarded as critical facilities that should not be sited over the trace of an active or potentially active fault.

d. The potential effects of dam or levee failure are so substantial that geologic and engineering investigation is warranted as a prerequisite for authorizing public and private construction of either the facilities or development in affected areas.

e. Though flooding from dam failure and tsunamis can be, it seems, expected on a limited scale, the precise limits of the flooding is not known. It would follow that the City formulate emergency plans that might relieve the impact of such flooding in the event of an earthquake.

6530. Recommendations:

a. Governments, including the City of Foster City, in seismically active areas, or areas subject to flooding resulting from seismic activity should work individually and cooperatively to evaluate facility vulnerability and identify areas where flooding could result from earthquakes.

b. Governments, including the City of Foster City, in seismically active areas should work to establish adequate standards and tests for dams and levees.

c. Governments, including the City of Foster City, in seismically active areas should adopt plans, policies, and procedures, and enact legislation to implement the above policies.

d. To resolve the unknown factor of flooding, it is recommended that the City of Foster City, together with other possibly affected cities in San Mateo County, consider the funding of a definitive study to determine the actual extent of possible flooding from failure of Crystal Springs and San Andreas Dams, and from the effects of a tsunami.

6600. Liquefaction

6610. Findings:

a. Catastrophic failures in recent earthquakes demonstrate that liquefaction poses a major threat to the safety of engineered structures. Major landslides, settling and tilting of buildings on level ground, and failure of water retaining structures have all been observed in recent years as a result of this type of ground failure.

b. It has been determined that the liquefaction potential in Foster City is low at worst and non-existent at best.

c. The levee system in Foster City has been determined to meet the current seismic standards of the Federal and State governments.

d. The bridge system in Foster City has been determined to be safe by State standards.

6620. Policies:

a. The policies instituted since the inception of Foster City, regarding maintenance of the bridge and levee systems, should be maintained.

6630. Recommendations:

a. It should be the attitude of the City of Foster City to have the bridges and levees checked independently every five to ten years, by either a private consulting firm or by the State, to determine if they meet seismic safety standards.

6700. Structural Safety and Risk

6710. Findings:

a. It has been determined that the construction of buildings in Foster City has been developed with the intention of reducing the impact of differential settlement as much as possible.

6720. Policies:

a. That the continuation of policies instituted in the 1960's regarding methodology of foundation design be maintained throughout the remainder of construction in Foster City.

6730. Recommendations:

a. It must be recommended that the City of Foster City be aware, through its Building Department, of any new technological advances in foundation design that might resolve the differential settlement problem. If these improvements come about and they sufficiently supersede the old standards, that they be adopted.

7000. *IMPLEMENTATION*

7100. Since to disregard the possibility of a major earthquake taking place in the San Francisco Bay Area and affecting Foster City would be unconscionable on the part of the City, it is the attitude of the City of Foster City in this document to examine the extent and significance of Disaster Preparedness Planning and how it can be used to mediate the effect of a major earthquake. It should be noted in the inception of this report, that the discussion herein is only a general statement of what Disaster Preparedness Planning should and must involve. It is, therefore, the intention of this document to be merely a general review of the nature and extent of Disaster Preparedness Planning from the standpoint of the national, state, county, and local levels of government. A more detailed discussion of Disaster Preparedness Planning at the Foster City level will be found in the Safety Element of the City of Foster City's General Plan.

7200. THE PURPOSE OF DISASTER PREPAREDNESS

7210. The primary responsibility for a program of disaster relief is that of the local jurisdiction. The State is responsible for coordinating these individual efforts, in order to provide relief if the disaster reaches regional proportions. The expected extent of damage from a major earthquake may require each of the cities of San Mateo County to function for an extended period of time using its own resources. Therefore, it is imperative that each city review its Disaster Preparedness Program to rectify the negative findings of similar programs in cities where it has been necessary to implement them.

7220. The purpose of disaster preparedness is to safequard people in natural emergencies. Disaster preparedness in action is the coordinated response of federal, state, or local government -- often working together -- to an extraordinary emergency. The response calls for effective application of all available resources, as needed. The development of local capabilities for effective action in emergencies is essential to disaster preparedness.

7230. Disaster preparedness is not a separate function set apart from the normal responsibilities of government. On the contrary, disaster preparedness operations occur whenever a local government responds to any extraordinary emergency -- such as a tornado, forest fire, hurricane, earthquake, flood or other natural disaster; a major explosion or accident, or the release of radioactive materials or toxic chemicals; or an unusual peacetime emergency such as a civil disorder.

7240. Disaster preparedness is not a special unit or group of people standing by to "save the day" in case of a major disaster. Existing local government forces form the nucleus of preparedness, around which doctors and hospital staffs, the news media, industry, volunteers, and other groups organize. It is the need for Coordinated Emergency Operations involving all governmental

and nongovernmental groups with the capacity to help save lives or minimize damage, that distinguishes extraordinary emergencies from the emergencies that local fire and police forces, or hospitals and doctors, deal with everyday.

7250. Disaster preparedness means that a jurisdiction is prepared to respond promptly to save life and protect property if it is threatened or hit by an emergency of any type, utilizing all available resources. This requires that planning be done and preparedness actions be taken before there is an emergency. The whole concept of emergency readiness can be summed up by saying that the forces of government, and all others with emergency missions, must be able to "do the right things at the right time," when the chips are down. This includes the ability of key executives to coordinate the operations of police forces, fire forces, ambulances, hospitals, medical personnel, radio and television stations, and all other people and units able to help citizens under conditions of extraordinary emergency.

7260. Each community should have an Emergency Operating Center (EOC) from which key officials, such as the City Manager, Police Chief, and Fire Chief can exercise direction and control in extraordinary emergencies.

7270. An EOC should be located in an earthquake resistant building. It should be equipped with all maps and displays permanently in place so that key executives can understand the emergency situation as it develops. The facility should have all communications permanently in place, including those to local emergency forces (police, fire, hospitals, etc.) and to the State EOC. Also, there should be a direct or indirect means of access to the Emergency Broadcast System. The EOC should, if possible, be in regular use 24 hours a day, by police or fire departments.

7280. Each community needs an emergency communications system that will permit its key executives to direct and control emergency operations. The communications used day-to-day by police, fire, ambulance, public works and other forces provide the basis for the emergency communications system. However, additional equipment such as power generators may sometimes be needed, and should be placed in or linked to the Emergency Operating Center to permit coordinated operations in an emergency.

7300. SAN FRANCISCO BAY AREA EARTHQUAKE RESPONSE PLANNING PROJECT

7310. The President's Office of Emergency Preparedness (OEP) sponsored a study with the National Oceanic and Atmospheric Administration (NOAA) which sets forth the probable effects of a major earthquake in the San Francisco Bay Area. The NOAA/OEP study postulates six possible earthquakes with Richter magnitudes of 6.0, 7.0, and 8.3, and with epicenters located on the Hayward Fault and the San Andreas Fault. A descriptive analysis of the damage which could conceivably result from these quakes has been conducted. The NOAA/OEP study details the effects of each of the six potential earthquakes on facilities and resources in the Bay Area which are essential to emergency recovery; hospitals, laboratories, blood banks, ambulance services, government buildings, schools, the mass media, and the utility, communication and transportation system. Potential injury to major dams and the obvious effects of their possible rupture were also analyzed.

7320. Now that the NOAA/OEP study has been completed, OEP, the Governor's Office of Emergency Services (OES), and the local governments concerned are developing a Bay Area Earthquake Response Plan. To accomplish this, the State OES has established a Planning Research Center in the Bay Area. The staff consists of professional planners funded by the Federal government, planning personnel from the State OES, and personnel from 22 State agencies which have been assigned emergency responsibility by the Governor's Administrative Order.

7330. The Planning Research Center is developing plans which will coordinate the actions of local governments with State and Federal support operations. The plan will also encompass the resource capability of the private sector. Through the close cooperation of Federal, State, and local representatives, a plan which is responsive to the needs of the entire Bay Area will emerge.

7340. The Earthquake Response Plan will encompass California's long standing system of Mutual Aid, which forms the foundation of the State's emergency planning. Under this concept each local jurisdiction relies first on its own resources, then calls for assistance from its neighbors -- city-to-city, city-to-county, county-to-county, through one of the regional offices of OES to the State, and finally, as needed to the Federal government.

7350. The objective of the proposed planning project is the development of a comprehensive Emergency Operations Plan detailing the actions to be taken by local, State and Federal governments and by appropriate non-governmental organizations in response to a major earthquake in the San Francisco Bay Area. The Emergency Plan will include, but not be limited to actions necessary to: 1) limit loss of life and property; 2) care for displaced and injured people; 3) evacuate people from areas that are threatened by the hazards that may follow the initial impact of an earthquake (such as ensuing fires, landslides, potential dam failures, or aftershocks); 4) provide traffic supervision and control along established evacuation routes and security for evacuated areas; 5) rescue people trapped in damaged structures or isolated danger areas; 6) provide necessary fire prevention, firefighting, and lifesaving services in affected or threatened areas; and 7) relieve hardship and expedite rapid and orderly reconstruction and redevelopment.

7400. STRENGTHENING OF BASIC RESEARCH PROGRAMS IN SEISMOLOGY

7410. A healthy research program in seismology is essential to the understanding of earthquakes and the reduction of earthquake hazards in California. Although basic research should continue to be supported by the Federal government, a modest program supported by the State should be carried out to emphasize the State's responsibility to its citizens in this field. Clearly, Foster City would benefit from such a program.

7420. Particular emphasis should be placed on research of unique value to California that can best be carried out by California agencies and institutions. The geodimeter program along the San Andreas Fault is an example of this effort, as is the long term gathering of epicenter data and its analysis by the University of California and several private universities.

7430. From time to time, certain new observatory instruments are developed which can be tested best under California conditions. The State should not hesitate to join Federal agencies in giving at least some initial support to these fresh research approaches.

7440. The State should give favorable consideration to the Joint California Universities Earthquake Hazard Proposal. Economic support by the State, as well as by Federal agencies, for this coordinated program might be looked upon as a prudent minimal investment to ensure that first class research by scientists in the State can go forward on the earthquake problem.

7450. The State has a responsibility to ensure that a long term record of basic information on California earthquakes be properly kept. This requires continuously monitoring and analyzing seismic events, both on land and off shore. The University of California, Berkeley, in the northern part of the State, and California Institute of Technology in the southern part, have a long history in carrying out this responsibility. Both networks are underfunded in view of current needs and responsibilities; even though inadequate at current levels, the funding for the California Institute of Technology network is also tenuous. Their efforts should be supported by firm and adequate funding, including financial support by the State, and the effort should be expanded.

7460. Expansion is urgent in the light of the rapid increase of State population and industry. The data collected and analyzed should include such important features as the earthquake magnitudes, precise locations of epicenters, the depth of foci and the general seismicity of California. This is regarded by engineers, planners and others as of fundamental importance in coping with the problems of earthquakes.

7470. It must be stressed that the networks operated by the universities also provide the basic information for research on seismology by the seismologists at those institutions and by graduate students in seismology. This team of highly trained and competent seismologists is an essential contribution of the State to understand earthquakes, not only in California but throughout the world.

7480. There is also need in California for special purpose networks of seismographs of a modern type. This special purpose network should have adequate funding to enable continuous analysis and study of the seismograms obtained.

7490. The State could make a considerable contribution in reducing the cost of maintaining the networks if it would make its microwave communications system throughout the State available essentially without charge to the university and State groups with need to telemeter seismic signals. This would enable the universities to link the out-stations to the central observatories at Berkeley and Pasadena, for example, without the great costs of telephone-telemetry lines that duplicate the State microwave system. The State could contribute to the further reduction of unnecessary duplication and costs by encouraging all groups now operating seismographs in California, be it with Federal, State, or other financial support, to increase the present real-time exchange of seismic data by expanded use of telemetry which permits one seismometer to transmit continuously to two or more recording centers (Governor's Earthquake Council, December 28, 1972, p. 31-33).

7500. FOSTER CITY EARTHQUAKE EMERGENCY PLAN

7510. Susceptibility to structural damage is related to intensity and duration of seismic disturbance. It can be realistically presumed that an intensity of or greater than a magnitude 5 Richter for a duration of twelve seconds would be necessary to cause significant damage. The Foster City Emergency Plan, however, is activated by any ground movement that is sufficient to cause concern.

7520. The Plan:

7521. All off-duty fire, police, public works and staff personnel are summoned to report to their respective places of work.

7522. The Emergency Operating Center (Public Safety Building) is activated.

7523. Pacific Gas and Electric Company is alerted.

7524. Patrols are assigned as follows:

a. Fire Division - Companies respond to pre-assigned areas to assess structural damage, effect rescue, and confine fires.

b. Police Division - Patrol cars respond to pre-assigned areas to give public instruction (they have public address capabilities), assess damage to streets and bridges, direct evacuation and effect traffic control.

c. Public Works - Assigns patrols to inspect levees, water system, bridges and streets. Public Works personnel and equipment may be assigned to assist in heavy rescue.

d. Recreation - Prepare to establish temporary housing for displaced persons. The Recreation Center, public schools, and churches are committed to such housing. Persons will be assigned to each according to maximum capacity (there are eight public buildings with a total capacity of 1,100 persons).

7525. Considerations:

a. Shut off zone control valves to stop flow of gas, water and/or electricity into areas evidencing main breakage or interruption.

b. Stop all incoming traffic except emergency related vehicles.

c. Re-route incoming emergency vehicles in the event of bridge or overpass collapse.

d. Secure available food supplies - control dispensing of food supplies from retail outlets. Prevent hoarding and/or looting.

e. Organize medical volunteers to provide aid at temporary shelters.

APPENDIX A

Congressman Paul McCloskey conducted hearings in San Mateo County in August of 1969 to reexamine the findings of the Congressional Subcommittee. The comments made by McCloskey and others place the issue of seismic safety and the levee system in proper perspective. It must be remembered that the Federal Housing Administration and the Veterans Administration both reinstated Foster City for federal mortgage insurance guarantees. The following statements are taken from the McCloskey hearings held on August 26, 1969:

> MCCLOSKEY: "The most important thing that must occur in order for Foster City development to proceed, at least as to those subdivisions not already approved by the FHA and VA---the most important thing that must occur is for the Corps of Engineers and the FHA to agree on whether or not they will require a dike stability underseismic loading conditions of 1.0:1 safety factor rather than the 1.5:1 safety factor which the FHA has indicated it will require in the future. Now this is somewhat technical, but I'd like to say that a 1.5:1 safety factor is apparently accepted on all hands, all sides, as an appropriate safety factor for cut and fill operations under stable circumstances, but when you get into the uncertainties of earthquake hazards, there is very real doubt as to whether a 1.5:1 requirement is realistic, and I might demonstrate that by saying that if a 1.5:1.0 safety requirement were imposed for all developments in San Mateo County, all building would stop very probably, or most of it, not just in Foster City. And it may be impossible to impose a 1.5:1 safety factor on all FHA insured developments, at least in the 24 states in this country that have seismic potential problems, or landslide problems. Now, I keep stressing the 1.5:1 because there is evidence that until recently the Corps of Engineers in its own practices has accepted a 1:1 safety factor under these measuring criteria, and I dispute, and Mr. Foster '(T. Jack Foster)' disputes, and I think he is right, there is certainly nothing in the report that 1.09:1 under earthquake circumstances was going to mean that the dikes would probably fail in the event of a major earthquake of the 1906 variety. But since the Corps accepts a 1:1, or has elsewhere, the question now is, will they accept it in the future and will FHA accept it in the future when the FHA's procedures have come under such heavy attack, and again let me say properly, under heavy attack by the Government Accounting Office which is a watchdog agency in the government."

APPENDIX B

The following statement by Congressman McCloskey denotes the real reason for the Congressional Subcommittee Hearings dealing with seismic safety in California, of which McCloskey was a member:

> MCCLOSKEY: "This was purely an inquiry into whether the FHA had adequate procedures in areas of seismic risk and whether they have followed these procedures or not, and it was exacerbated by the fact that FHA had represented that it would do one thing and then had not done it with respect to its procedures. So once these facts were ascertained, the Special Studies Subcommittee which was looking into federal procedures was not interested and didn't extend its inquiry on the question of the merits as to what kind of engineering should be required. They were interested solely in procedure and it -- there's nothing in the hearings or in the report, with the exception of one statement indicating -- I think the way they put it was that the FHA accepted the developer's Improvement Plan and accepted a 1.09:1 earthquake safety factor although they had been advised by their own experts, who are the National Academy of Sciences, that a 1.5:1 safety factor should be required, and the government was -- or Congress was critical of FHA for doing that although I don't think they should have been because the report that recommended the 1.5 did not come until 1965, as I recall, and the FHA had approved this back in 1961. And what the Congress said was, well, once you got that 1.5 ratio and here was a subdivision you had approved four years earlier at 1.09:1, you should have followed up and done something. But that doesn't indicate the true merit of the question as to whether 1.09 is as safe as you will ever get in California, and this is why I don't think it is proper to criticize the committee for not going into the question of what was right and what was wrong. Once they had ascertained that FHA wasn't doing its job, their responsibility ended, and it's unfortunate that cloud and doubt is thrown on the safety of Foster City homes because of FHA procedural deficiencies. I know of no scientific evidence that these dikes would fail in the event of a 1906-type earthquake; there was none in the hearings, and I have read everything I can find on the subject and I find nothing to support from any engineering standpoint or geological standpoint any predictions or speculation that these dikes will fail, or even if a crack opened up that Foster City would be materially damaged."

APPENDIX C

The next series of statements will clarify the significance of the 1:1 and 1:5 ratio that seems to be so crucial in the structural integrity of the levee system. Later, in Appendix D, in a letter from Kenneth F. McIntyre, dated May 18, 1969, then a Lieutenant Colonel, United States Army Corps of Engineers, and Assistant Director of Civil Works for the Pacific Division to Congressman John S. Monagan, a more technical explanation of the 1:1 and 1:5 ratio will be given.

> MCFADDEN: "I have a question, Mr. Chairman, to Congressman McCloskey to see if I can clarify my understanding of this 1.0:1 and 1.5, and possibly others on the Board are not sure of this, too. Does this mean, when you speak of this seismic reading or tolerance, whatever it is -- Does this mean that if it were 1.5 we could then increase the heights and/or widths of the dikes and thereby resolve this problem? Are we talking about the dikes now, Congressman, or are we talking about the soil upon which the home rests?
>
> MCCLOSKEY: "It's entirely the dikes. That's an excellent question because -- the ratio means this. For cut and fills, for highways, for landslides, or foundations, for anything you are going to construct where you cut into the earth and then fill it, the entire scientific community recognizes that a safety factor of 1.5:1 is appropriate. And as I understand it, and maybe, Jack, you can check me if I'm wrong, but a 1.5:1 ratio, all it means is that you take all known possibilities that can occur, and if you design your structure strong enough to withstand those possibilities, you've got a 1:1 ratio, and if you design it half again as strong to face all known possibilities, you've got a 1.5:1 ratio. But when you get into earthquakes, with the lateral shaking or movement of land, and you try to say, all right we think a shake can occur in this area based on the 1906 earthquake, or the 1836 earthquake, that will have a lateral force of this. Then our dikes must be built strong enough to withstand that further lateral movement as well as the loading of the force of the tides or whatever you are designing for. Now when you get into earthquakes, the uncertainties are so great that to say you need a 1.5:1 ratio to withstand lateral movement of earth, you are bordering on speculation and uncertainty and it may be impossible to achieve. Because you are saying, what are the known factors so that we can devise a 1.5:1, and the geologist must concede that there are certain factors that are unknown in this lateral movement. So -- if -- and the reason I was late, I was talking with Bill Moore, who, in Washington, is recognized as one of the great earth scientists, perhaps the leading authority in the country... . He was on the Committee of the National Academy of Sciences which gave the opinion to FHA in 1965 that a 1.5:1 ratio was essential for the ordinary situation, but he didn't mean to infer, and he says the committee didn't mean to infer that 1.5:1 was necessary for seismic loading or earthquake hazards, and that if you went -- as he said, if you went to 1.5:1 for earthquake loading, there's not a building here on the Peninsula that would meet those standards."

MCFADDEN: "Let me ask this, then, if -- Now I understand that aspect of it. Do we have any general idea of what -- if we had to go to 1.5 for our dikes here in Foster City, speaking solely of Foster City ... is there any engineering or FHA or Corps of Engineers or anyone that can give us some indication of what that would mean? I mean, would it mean we have to add so many feet to the dikes, or costs or what? Do we have any idea of what we are talking about here. Or is this a totally unknown factor?

MCCLOSKEY: "I think its a totally unknown element. I have heard it suggested that it may be impossible to achieve a 1.5:1 dike stability against lateral movement."

T. JACK FOSTER: "First of all, I have read every word of the hearings of the committee and I have read the committee report, and it seems, while the Congressman has a duty to criticize federal employees, I am going to kind of jump on the Congressional committee just a little bit. I think ... One of the things that was never asked was what would happen if there were a break in the levees? This chart shows the relationship of the levees and the houses and the land to the Bay, and I think it shows that we would not have under any set of circumstances a catastrophe that it would if a bank slid out from under a hillside development or a Hurricane Camile or any of -- where a levee along a river washes out. Because you see what we have here ... is a vertical scale, or to put it another way, we have taken a cross section of Foster City and squeezed it up real tight in order to make it somewhat easier to read. But here we have along this section the east shore levee, 108, and the land right behind it is at about 107. Now that's for a distance of some 400 feet. And the levee section, as was pointed out in the hearings, is always weakest at mean low tide, or low tide, which is right here, because there's less water holding it down on the outer side. These little peaks here represent the floors of the houses. Now, the highest tide ever recorded is 106.2. Now, at the highest tide mark, you would have water on the floors, assuming it could get --- after it slipped through --- the levee broke and it got through about 400 feet of land in back of the levees, you would have water in these houses right here to a depth -- how the greatest area would be at 104, a depth of about two feet of water in these houses on the island after the -- if you should happen to have a dike failure and a highest tide of record all at the same time, and you would only have that for the instant of the highest tide before it starts to ebb again at this point."

"I think the Corps in 1961, prior to doing all the work Mr. Shannon referred to and all the other things, said that the levees were safe, and even under excessive loading they were "fairly safe," with a safety factor of 1.09 -- so -- I am, you know, I am comfortable behind the levees. The

purpose of this is to demonstrate that should we have a big earthquake and the safety factor drops down below one point, to where some night it could slip out -- now I might point out that 1.09 was made on the most critical levee section. They took several sections, and the worst was 1.09, so everything else is better. I don't think we have a calamity on our hands... ."

APPENDIX D

As was noted earlier in Appendix C, Colonel McIntyre wrote a letter to Congressman Monagan, denoting the significance of the 1:1 to 1:5 ratio. McIntyre gave a more technical discussion of these ratios. He also offers a brief statement about the issue of tsunamis in San Francisco and their impact on Foster City. It should be noted that a fuller discussion of the tsunami issue is given in the Tsunami Section. The McIntyre letter follows:

> "You will recall we stated that a safety factor for levee stability of 1.09 to 1.0 has been computed for the Brewer's Island levee using the assumed levee section described in our previous letter and assuming a horizontal earthquake loading equivalent to one-tenth of the force of gravity. This factor of 1.09 is the ratio of available soil shear strength at an assumed potential failure surface to the shear loading equal to one-tenth of the weight of the soil. This horizontal loading was from examination of a number of potential failure surfaces within the levee and foundation and was considered to be the most critical ratio for the assumed conditions.
>
> Mr. Wasserman inquired as to how the above-mentioned safety factor related to possible overtopping of the levee by a tsunami or sea wave caused by an earthquake. As you may gather from the above explanation of the computed safety factor, it is not related to the effects of a tsunami.
>
> In some coastal areas possible high water levels caused by tsunamis would be critical in determining the design height of a levee. However, the configuration of San Francisco Bay and the Golden Gate are not conductive to generation of high water levels in the bay from tsunamis developing in the Pacific Ocean and we understand that stage records in the bay have shown little effect from tsunamis in the Pacific. The design levee height for the Brewer's Island levee was based on maximum recorded storm tide levels in the bay with allowance for runup and waves resulting from high winds over the bay itself and an additional allowance for freeboard."

APPENDIX E

Extracted originally from Federal Housing Administration letter from J. Frank Pendergast, Director, to T. Jack Foster & Sons dated September 24, 1962 specifying certain general requirements for Levee Construction in Foster City:

F-3 Levee Construction

a. Levee Heights: All levees will be constructed to the required heights as shown below prior to beginning of any residential construction. The levee heights are based on M.S.L. (Mean Sea Level Datum).

   (1) North Levee - North Levee from the tide gate structure on Seal Slough to the San Mateo Bridge shall be constructed and maintained to a minimum 9.8 feet.

   (2) East Shore Levee - East Shore Levee from the San Mateo Bridge south to Belmont Slough shall be constructed and maintained to a minimum 9.0 feet.

   (3) Belmont Slough Levee - Levees along Belmont Slough shall be constructed and maintained to a minimum 8.1 feet.

   (4) Seal Slough Levee - Levee shall be constructed and maintained to a minimum 6.5 feet. This levee height will be subject to reappraisal in the future as development proceeds. When interior ponding has been reduced beyond permissible limits, (as determined by FHA) it will be necessary to construct and maintain this levee to 8.1 feet.

b. Levee Cross Sections: The levee cross sections and slopes proposed in Estero Municipal Improvement District, hereafter called EMID, Supplemental Levee System Report dated May 21, 1962, as revised by the above required levee heights are considered acceptable.

c. Levee Slope Protection:

   (1) The sponsor's proposal for rip rap protection in EMID Supplemental Levee System Report dated May 21, 1962, is considered acceptable for existing levees providing the maintenance program proposed in the Sponsor's report of May 22, 1962, is effectively followed.

   (2) For new levees, the rock protection shall meet the recommendations of the Corps of Engineers, i.e.;

      (a) Outer layer - 36 inches in thickness with a minimum size stone of 500 pounds.

      (b) Intermediate layer - 16 inches in thickness with a minimum size stone of 50 pounds.

      (c) Filter layer - 6 inches minimum thickness of filter graded sand and gravel.

d. Fill Controls: (Omitted - not pertinent to levee system)

e. Maintenance of Levee Heights: The proposed initial overbuilding, inspection, and maintenance program proposed in the EMID Supplemental Levee System Report dated May 21, 1962, is considered satisfactory for maintaining minimum levee height elevations.

GLOSSARY

ALLUVIUM: A general term for the sediments laid down in river beds, flood plains, lakes, fans at the foot of mountain slopes, and estuaries during relatively recent geologic times, which are generally unconsolidated.

AMPLIFICATION: The increase in earthquake ground motion that may occur to the principal components of seismic waves as they enter and pass through different earth materials.

AMPLITUDE: Maximum deviation from mean or center line of wave.

ANOMALY: A deviation or inconsistency of a specific land feature from uniformity with the larger area.

ARTIFICIAL FILL: Earth and other types of materials, either non-engineered or engineered fill (properly placed and compacted) placed by man.

ATTENUATION: Drying out (decay), reduction of amplitude or change in wave due to energy dissipation or distance with time.

ATTITUDE (OF ROCK STRUCTURES): Nomenclature including the terms dip and strike, the attitude of the flat surface of a sedimentary bed, whether included or not, is referred to the horizontal plane. Dip is its slope inclination (in degrees) from this plane, and is measured with a clinometer. Strike is the compass bearing on the line of intersection of its surface with the horizontal plane. The terms may also apply to faults, veins, and dikes, or any natural surface.

BASALTIC: Pertaining to or composed of basalt: a dark to medium-dark color, commonly extrusive (locally intrusive, as dikes) mafic, igneous rock.

BED: The smallest division of a stratified series, marked by a more or less well-defined plane from its neighbors above and below.

BEDDING PLANE: In sedimentary or stratified rock, the division planes which separate the individual layers, beds or strata.

BEDROCK, GEOLOGIC: A general term for rock that underlies soil or other unconsolidated materials.

BLOCK, CRUSTAL: A distinct portion of the earth's crust, usually defined by tectonic features along its boundaries.

CLASTIC: A textural term applied to rocks composed of fragmental material derived from pre-existing rocks or from the dispersed consolidation products of magmas or lavas.

CLAY: The term carries three implications: 1) particles of very fine size, less than 1/256 mm, 2) a natural material with plastic properties, 3) a composition of minerals that are essentially hydrous aluminum silicates.

COLLUVIUM: Loose, cohesionless soil material or loose rock deposited by creep, landslides and surface wash; over four feet thick, subject to downslope creep and surface failure; a gravity deposit as opposed to alluvium, which is transported by blowing water.

COMPACTION: Decrease in volume (void space) of sediments as a result of compression.

CONSOLIDATION: Reduction in volume and increase in density, often by removal of intergranular water.

CONTACT (GEOLOGIC): A plane or irregular surface between two different types or age of rocks.

CONTINENTAL BORDERLAND: The area of the continent margin between the shoreline and the continental slope which is topographically more complex than the continental shelf; characterized by ridges and basins, some of which are below the depth of the continental shelf.

CONTINENTAL SLOPE: The zone around the continent extending from the low water line to the depth of which there is a marked increase of slope to greater depth.

CRUSTAL BLOCKS: See BLOCK, CRUSTAL.

CREEP: Imperceptibly slow, more or less continuous movement, experienced along faults, or with respect to downslope movement of a mass, as in a landslide.

CRUSTAL STRAIN: Deformation of the outer crust of the earth resulting from the application of tectonic forces.

DAM INUNDATION: Flooding which occurs as a result of dam failure.

DIFFERENTIAL DISPLACEMENT: Applies to irregularities in offset resulting from fault movement.

DIFFERENTIAL SETTLEMENT: Non-uniform or uneven lowering of the ground surface.

DIP SLIP: Fault displacement parallel to the dip of the fault.

DISCONTINUITY: Sudden or rapid changes occurring with depth; in one or more of the physical properties of materials constituting the earth, as evidenced by seismic data.

DISSECTION: The work of erosion in destroying the continuity of a relatively even surface by cutting ravines or valleys into it.

DROWNED: To submerge (land) with water, whether by a rise in the level of a lake, ocean, or river, or by the sinking of the land.

DYNAMIC ANALYSIS PROCEDURES: Techniques for analysis of how buildings react to earthquake accelerations.

EARTHQUAKE: Group of elastic waves propagating in the earth, set up by a transient disturbance of the elastic equilibrium of a portion of the earth.

EPICENTER: The point on the earth's surface vertically above the focus of an earthquake.

ESSENTIAL SERVICES: Services necessary for the restoration of order following a catastrophe and the maintenance of public safety and health.

EXPANSIVE SOILS: Those soils which experience volumetric changes resulting from a change in content of moisture and the degree of expansivenss of the clay content.

EXTRUSIVE: Maga (molten rock) or magmatic materials poured out or ejected at the earth's surface.

FACIES: The aspect of belonging to a geologic unit of sedimentation including mineral composition, type of bedding, etc.

FAULT: An earth fracture or zone of fractures along which the rocks on side have displaced in relation to those of the other, in response to the accumulation of stress.

Active Fault: One along which displacement has occurred within about the last 11,000 years (Holocene time), or which has exhibited historic earthquake activity.

Potentially Active Fault: A fault along which displacement has occurred during the last two to three million years (Pleistocene time) but not proved by direct evidence to have moved within the past 11,000 years.

Inactive Fault: Any fault along which displacement has not occurred during the past two to three million years.

Hypothetical Fault: A fault whose existence is based on indirect data. A fault which is invented to explain anomalies or variations in geological or geophysical data.

FAULT BLOCK: A body of rock bounded by one or more faults.

FAULT CREEP: Very slow, periodic or episodic movement along a fault trace unaccompanied by earthquakes.

FAULT SCRAP: The cliff formed by a fault; most fault scraps have been modified by erosion since faulting.

FAULT SYSTEM: Two or more fault sets formed at the same time.

FAULT TRACE: The intersection of a fault and the earth's surface as revealed by dislocation of fences and roads and by ridges and furrows in the ground.

FAULT ZONE: A fault, instead of being a single clean fracture, may be a zone hundreds or thousands of feet wide; the fault zone consists of numerous, interlacing, small faults or a confused zone of gouge, breccia, or other material.

FLOWS: Movement within displaced mass, such that the form taken by moving material or the apparent distribution of velocities and displacements resemble those of viscous fluids; slip surfaces within moving material are usually not visible or are short-lived.

FOCUS: The point within the earth which marks the origin of the elastic waves of an earthquake.

FOLD: A bend in rock strata.

FOLD AXIS: A line where a folded bed shows maximum curvature; the line formed by the intersection of the axial plane of a fold with a bedding surface.

FORMATION: A rock body; an assemblage of rocks which have some character in common; applied to a particular sequence of rocks formed during one epoch; a rock unit used in mapping.

FRACTURE: Break in rocks due to faulting or folding.

FREQUENCY: The number of seismic wave peaks which pass through a point in the ground in a unit of time, usually measured in cycles per second.

FRIABLE: Said of a rock or mineral that crumbles naturally or is easily broken, pulverized, or reduced to powder; a soil consistency in which moist soil material crushes easily under gentle to moderate pressure and coheres when pressed together.

GEOLOGIC HAZARDS: Geologic features or processes that are dangerous or objectionable to man and his works; they may be natural phenomena or man-induced phenomena.

GEOLOGIC MAP: Map showing distribution of formations, folds, faults, and mineral deposits by appropriate symbols.

GEOLOGIC SECTION: A graphic representation of geologic conditions along a given line or plane of the earth's crust.

GEOLOGY: The science which studies the underlying material found beneath the earth's crust.

GEOMORPHOLOGY: The branch of geology which deals with the form of the earth, the general configuration of its surface, and the changes that take place in the evolution of landforms.

GEOTECHNICAL: Relating to the geological aspects of engineering and the application of scientific methods and engineering techniques to the management of natural resources; includes consideration of the physical and bulk properties of soils, surface deposits, and solid rocks, as well as seismicity and hydrology.

GRANITIC: Pertaining to or composed of granite, a term loosely applied to any light colored, coarse grained, plutonic rock containing quartz as an essential component, along with feldspor and mafic minerals.

GRAVEL: Natural accumulation of small, rounded stones and pebbles over 2 mm in diameter, or a mixture of sand and small stones.

GROUND CRACKING: Cracks usually occurring in stiff surface materials, resulting from differential ground movement.

GROUND DISPLACEMENT: The relative movement of the two sides of a fault at the surface of the earth; and measured in any chosen direction.

GROUND FAILURE: A situation in which the ground does not hold together, such as in landsliding, mud flows, liquefaction, and subsidence.

GROUND RESPONSE OR MOTION: A general term including all aspects of motion (acceleration, particle velocity, displacement, stress and strain), usually resulting from a nuclear blast or an earthquake.

GROUND WATER: Water beneath the surface of the ground in a saturated zone.

HOLOCENE: The time period from the close of the Pleistocene or glacial epoch through the present; synonymous with recent; about the last 11,000 years.

IGNEOUS: Rock formed by solidification from a molten or partially molten state; one of the two classes into which all rocks are divided and contrasted with sedimentary rocks.

INTENSITY: A nonlinear measure of earthquake size at a particular place, as determined by its effect on persons, structures, and earth materials; the principal scale used in the United States today is the Modified Mercalli Scale; intensity is a measure of effects as contrasted with magnitude, which is a measure of energy.

INTRUSION: The process of emplacement of magma in pre-existing rock.

ISO-ACCELERATION MAP: A map consisting of lines connecting points of equal potential peak ground acceleration.

LANDFILL: A place where solid waste or earth is dumped, usually to dispose of garbage or to create new land for development.

LANDSLIDE FLOW: Soil and other colluvial materials that move downslope in a manner similar to a viscous fluid.

LATERAL SPREADING: Nearly horizontal failure surface; outward or horizontal extension, sometimes characterized by separation and cracking.

LEFT-LATERAL FAULT MOVEMENT: Generally horizontal movement in which the block across the fault from an observer has moved to the left.

LIFELINES: Services and facilities necessary for the basic functional maintenance of modern lifestyles (For example, public and private utilities, communication systems, and transportation network).

LIQUEFACTION: Liquefaction is the sudden large decrease of shearing resistance of cohensionless soil, caused by collapse of the soil structure by shock or strain, and associated with a sudden but temporary increase of the material into a fluid mass. Fine unconsolidated sand or silt, saturated with water, is particularly subject to liquefaction.

LURCHING: (Cracking, Fissuring) Under moderate to intense shaking, unconsolidated alluvium and soils may undergo various amounts of horizontal displacement toward adjacent unconfined areas. This may or may not be associated with liquefaction. Cracks and fissures, ranging from inches to many feet in length, and of varying widths, generally accompany this "lurching." Intervening ground movements are often tilted. Structures located on such ground can be severely tilted and disrupted.

MAFIC: Pertaining to or composed dominently of the magnesian rock-forming silicates; said of some igneous rocks and their constituent minerals.

MAGNITUDE: The rating of a given earthquake is defined as the logarithm of the maximum amplitude on a seismogram, written by an instrument of specified standard type, at a distance of 100 km from the epicenter. It is a measure of the energey released in an earthquake; the zero of the scale is fixed arbitrarily to fit the smallest recorded earthquakes; the scale is open ended, but the largest known earthquake magnitudes are near 8-3/4, every upward step of one magnitude means a 32 fold increase in energy release (thus, a magnitude 2 earthquake releases 32 times as much energy as a magnitude 6 earthquake); magnitude is not the same as intensity.

MANTLE: The layer of the earth between the crust and the core.

MAXIMUM ACCELERATION: Maximum excursion measured on an accelerogram.

MAXIMUM CREDIBLE EARTHQUAKE: The most potentially damaging earthquake that could ever occur on a given fault; the magnitude of such an event is usually obtained by using a deterministic approach, utilizing the principle that the length of the fault rupture is proportional to the magnitude of the earthquake caused by the rupture.

MAXIMUM PROBABLE EARTHQUAKE: The largest earthquake that on a statistical basis, will occur during a given period of time (commonly 100 years).

METAMORPHIC ROCK: A rock derived from pre-existing rocks by mineralogical, chemicals and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment at depth.

METAMORPHOSED: A rock which has undergone metamorphism (i.e., the mineralogical and structural adjustment of solid rocks to physical and chemical conditions which have been imposed at depth).

MICRO-EARTHQUAKE: A very small earthquake having a magnitude of 2 or less on the Richter Scale.

MICROSEISMIC EVENT: An earthquake or man-induced vibrations observable only with instruments.

MODIFIED MERCALLI: See INTENSITY.

MUDFLOW: A general term for a mass movement landform and process characterized by a flowing mass of predominantly fine-grained earth material possessing a high degree of fluidity during movement.

NORMAL FALUT: Vertical movement along a sloping fault surface in which the block above the fault has moved downward relative to the block below; a tensional fault.

OFFSET: In a fault, the horizontal component of displacement, measured parallel to the strike of a fault.

OVERBURDEN: Deposits that overlie bedrock, or rock materials that overlie useful rock or ore.

PARAPET: A low wall or similar appendage along the edge of a platform, roof, bridge or other structure.

PEAK GROUND ACCELERATION: The maximum acceleration of an earth particle, usually measured by an accelerometer.

PERCHED GROUND WATER: Unconfined ground water separated from an underlying main body of ground water from an unsaturated zone.

PERCHED WATER TABLE: The water table of a body of perched ground water.

PERIOD: The time (T) for one cycle; the time for a wave crest to traverse a distance equal to one wave length, or the time for two successive wave crests to pass a fixed point.

PERMEABILITY: The permeability of rock or unconsolidated material is its capacity for transmitting a fluid.

PHYSIOGRAPHY: A description of existing nature as displayed in the surface arrangement of the globe, its features, atmospheric and oceanic currents, climate, and other physical features.

PLATE: One of the large, nearly-rigid but still mobile segments or thin blocks involved in plate tectonics with a thickness of 50 - 250 km, including both crust and part of the upper mantle.

PLUTONIC: Of igneous origin; a general term applied to that class of igneous rocks which have crystalized at great depth and have therefore assumed, as a rule, the granitoid texture.

PORE WATER PRESSURE: Pressure or stress transmitted through the pore water (water filling the voids of the soil).

POROSITY: The proportion, usually stated as a percentage, of the total volume of a rock material that consists of pore space or voids.

POROUS: Containing pores, voids, or other openings which may or may not be interconnected.

QUICK CONDITIONS: Quick material becomes loose and incoherent; material that is in a soft, watery state (for example, quick ground).

REVERSE OR THRUST FAULT: Vertical to nearly horizontal movement along a sloping fault surface in which the block above has moved upward or over the block below the fault.

RIGHT-LATERAL FAULT MOVEMENT: Generally horizontal movement in which the block across the fault from an observer has moved to the right.

ROCKFALL: A relatively free falling or precipitous movement of newly detached segment of bedrock of any size from a cliff or other very steep slope; the fastest moving type of landslide; a mass of fallen rock.

SAND: Particles of sediment having a size range of 1/16 mm to 2 mm.

SAND BOILS: Turbid upward flow of water and some sand to the ground surface, resulting from increased ground water pressures when saturated, cohesionless materials are compacted by earthquake ground vibrations, characteristic of liquefaction.

SANITARY LANDFILL: A disposal area for solid wastes, where the wastes are compacted and covered by a layer of impermeable material, such as clay, daily.

SATURATED SOIL: Soil with zero air voids; a solid which has its interstices of void spaces filled with water to the point where runoff occurs.

SEDIMENT: Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its place of origin.

SEDIMENTARY ROCKS: Rocks formed by the accumulation of sediment in water (aqueous deposits) or from air (eoliar deposits); a characteristic feature of sedimentary deposits is a layered structure known as stratification or bedding.

SEICHE: A free or standing-wave oscillation of the surface of water in an enclosed or semi-enclosed basin (lake, bay, or harbor).

SEISMIC: Pertaining to shock waves within the earth produced by earthquakes, or in some cases, artificially produced shockwaves; pertaining to or caused by earthquakes.

SEISMIC BEDROCK: Naturally occurring earth materials, found either at or below the ground surface, that have a shear wave velocity of 2,500 ft./sec.; used in mathematical models for ground motion studies.

SEISMIC HAZARDS: Hazards related to seismic or earthquake activity.

SEISMICALLY TRIGGERED: An event which is caused by an earthquake or earth vibration which could be naturally or articially induced (that is, underground blasting; seismically induced.

SEISMICITY: A measure of the probability of an earthquake occurrence in an area.

SEISMOGRAPH: An instrument for recording earthquakes or seismic waves; the record made by a seismograph is called a seismogram.

SEISMOLOGY: The science of earthquakes and the study of seismic waves.

SETTLEMENT: The subsidence of surface material due to compaction, consolidation, or liquefaction.

SHEAR: A mode of failure whereby two adjacent parts of a solid slide past one another, parallel to the plane of contact; to subject a body to shear (similar to the displacement of the cards in a pack, relative to one another).

SHEAR STRENGTH: The stress or load at which a material fails to shear.

SHEAR WAVE: A body wave in which the particle motion is perpendicular to the direction of propagation.

SHEAR WAVE AMPLIFICATION: This implies increased particle motion.

SHEAR WAVE VELOCITY: The rate at which the shear wave travels.

SILICEOUS: Said of a rock containing abundant silica, especially free silica rather than silicates.

SLUMP: A landslide characterized by shearing and rotary movement of a generally independent mass of rock or earth along a concave slip surface (concave upward).

STRAIN: Deformation resulting from applied force; within elastic limits, strain is proportional to stress.

STRATA: Sedimentary rock layers.

STRATIGRAPHY: That branch of geology which treats of the formation composition, sequences, and correlation of the stratified (i.e., formed or lying in beds, strata, or layers) rocks as part of the earth's crust; pertaining to the discrimination, character, thickness, sequence, age, and correlation of rocks.

STRESS: Force per unit area.

STRIKE-SLIP: Fault displacement parallel to the strike of the fault.

STRONG MOTION: Ground motion of sufficient amplitude to be of engineering interest in the evaluation of damage due to earthquakes.

STRONG MOTION INSTRUMENTATION: Instruments which record intensity and magnitude of strong ground motion (i.e., measure of the oscillations of the earth's crust resulting from the passage of seismic waves through the earth).

STRUCTURAL: Pertaining to, part of, or consequent upon the geologic structure as, a structural valley; pertaining to buildings.

STRUCTURAL FEATURE: Features produced in the rock by movements after deposition, and commonly after consolidation of the rock.

SUBSIDENCE: Sinking or lowering of a part of the earth's crust.

SUBSIDIARY FAULTING: Generally minor faulting, associated with major fault breaks.

SURFACE RUPTURE: Breaks in the ground surface resulting from fault movement.

TECTONIC: Pertaining to or designating the rock, structure and external forms resulting from the deformation of the earth's crust, pressures causing such deformations often result in earthquakes.

TEXTURE: The physical appearance of a rock, as shown by size, shape, and arrangement of the mineral particles in the rock.

THRUST FAULT: See REVERSE FAULT.

TOPOGRAPHY: The physical features of the land, especially its relief and contour.

TORSIONAL RESPONSE PATTERN: Twisting of a building undergoing earthquake acceleration as opposed to swaying motion.

TRACE FAULT: See FAULT TRACE.

TSUNAMI: A sea wave produced by large areal displacements of the ocean bottom, often the result of earthquakes or volcanic activity; also known as seismic sea waves, or tidal waves.

UNCONSOLIDATED STRATA: Rocks consisting of loosely coherent or uncemented particles, whether occurring at the surface or at depth.

URBAN GEOLOGY: The application of geology to problems in the urban environment.

VELOCITY: A vector quantity which indicates time rate of motion; often refers to the propagation rate of a seismic wave without implying any direction (when used in this sense, the term is not a vector).

WATER TABLE: The upper limit of surface of the zone of saturation of ground water.

WEATHERING: Response of materials that were once in equilibrium within the earth's crust to new conditions at or near contact with water, air, and living matter; with time, the materials change in character and decay to form soil.

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